451-RFICD-GLAST/SN/GN

MISSION SERVICES PROGRAM OFFICE

Radio Frequency Interface Control Document (RFICD) between the Gamma-ray Large Space Telescope (GLAST) Observatory and the Space Network (SN) and the Ground Network (GN)

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Radio Frequency Interface Control Document (RFICD) between the Gamma-ray Large Space Telescope (GLAST) Observatory and the Space Network (SN) and the Ground Network (GN)

Need GLAST Names and Responsibilities

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Preface

The GLAST Observatory Radio Frequency (RF) Interface Control Document (ICD) defines all communication links between the Gamma-ray Large Area Space Telescope (GLAST) Observatory and the National Aeronautics and Space Administration (NASA) Space Network (SN), including the Tracking and Data Relay Satellite System (TDRSS). The RF communication interfaces are also defined between the GLAST and the NASA Ground Network (GN) with 11.3-m WGS at Wallops Island, 9-m MILA at Florida (TBD), and USN 13-m at Hawaii and Dongara, Australia.

The NASA Ground Network (GN) will include Universal Space Network (USN) ground stations as apart of Near Earth Network Service (NENS) contract.

For the remainder of this document, the GLAST Observatory will be referred to simply as the GLAST or Observatory.

This document is under configuration management of the Mission Services Program Office Configuration Control Board (MSPO CCB). Proposed changes to this document should be submitted to the MSPO CCB along with supportive material justifying the proposed change. A Document Change Notice (DCN) will be issued to update the document for any future approved changes.

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Section 1. Introduction

1.1 Purpose

This Interface Control Document (ICD) establishes performance requirements and defines and controls technical aspects of the Radio Frequency (RF) communications interfaces between the GLAST and the National Aeronautics and Space Administration (NASA) Space Network (SN), including the Tracking and Data Relay Satellite System (TDRSS). The RF communication interfaces are also defined between the GLAST and the NASA Ground Network (GN) ground stations:

- Wallops Island, Virginia Ground Station 11.3-m (WGS)
- Florida Ground Station 9-m (MILA) (TBD)
- USN South Point, Hawaii Ground Station 13-m
- USN Dongara, Australia Ground Station 13-m

1.2 Mission Description

The Gamma-ray Large Area Space Telescope (GLAST) is a joint mission with NASA and U.S. Department of Energy and institutions in France, Germany, Japan, Italy, and Sweden. It follows in the footsteps of the Energetic Gamma-Ray Experiment Telescope (EGRET) flown on board the Compton Gamma-Ray Observatory (CGRO). GLAST is a next-generation, high-energy gamma-ray observatory designed for making observations of celestial gamma-ray sources in the energy range extending from 10 keV to 300 Gev. The Gamma-ray Large Area Space Telescope (GLAST) mission begins a new epoch in space-based physics investigation. GLAST is part of the Structure and Evolution of the Universe theme, one of four major science themes within the NASA Office of Space Science. Through the SEU program, scientists seek to explore the limits of gravity and energy in the Universe, explain the structure of the Universe, and forecast our cosmic destiny.

GLAST is scheduled to launch February of 2007 by Delta Rocket. The intended orbit for the spacecraft is at an altitude of 565 kilometers with an inclination of 28.5 degrees.

1.3 Interface Responsibilities

The GLAST/SN interface responsibilities are defined in terms of the Goddard Space Flight Center (GSFC) GLAST Project Office and the GSFC Mission Services Program Office (MSPO), respectively. The portion identified as the GLAST is the responsibility of the GLAST Project Office. The portion identified as SN is the responsibility of the GSFC MSPO. The GLAST/GN interface responsibilities are defined in terms of the GLAST Project Office and the GSFC MSPO, respectively, for support with 11.3-m WGS at Wallops Island, 9-m MILA at Florida (TBD), and USN 13-m at Hawaii and Dongara, Australia.

Design requirements and parameters in this ICD are subject to the bilateral control of the GLAST Project Office and the GSFC MSPO, as appropriate for support through the SN and the Wallops Island, MILA Florida (TBD), USN Hawaii, and USN Dongara, Australia portion of the GN. The GLAST Project Office Manager and the designee of the GSFC MSPO will jointly approve the ICD upon resolution of issues and discrepancies as agreed upon by both parties. The MSPO CCB will manage and control this ICD.

1.4 Interface Identification

1.4.1

The communications interfaces defined and controlled by this ICD are the RF transmission links between the GLAST and the SN, and between the GLAST and 11.3-m WGS at Wallops Island, 9-m MILA at Florida (TBD), and USN 13-m at Hawaii and Dongara, Australia of the GN. The SN consists of a constellation of geosynchronous satellites known as Tracking and Data Relay Satellites (TDRSs) and associated ground systems. These ground systems include the dedicated ground element known as the White Sands Complex (WSC), which is comprised of the Second TDRSS Ground Terminal (STGT), White Sands Ground Terminal (WSGT), and Guam Remote Ground Terminal (GRGT). Section 3 specifies the high-level interface requirements for GLAST support by the SN and GN. Section 4 specifies the functional and performance characteristics for TDRSS links as well as for the 11.3-m WGS at Wallops Island, 9-m MILA at Florida (TBD), and USN 13-m at Hawaii and Dongara, Australia Ground Stations. For the remainder of this document, TDRSS refers to the Tracking and Data Relay Satellite (TDRS) and the White Sands Complex (WSC), while the ground stations listed above are referred to collectively as the GN. This ICD does not apply to the RF links of any other spacecraft/vehicle, tracking system, or dedicated ground terminal. Figure 1-1 depicts all GLAST communication links and interfaces.

1.4.2

The RF link calculations contained in Appendix A for the Observatory modes of operation are included only as supporting data and do not constitute a formal part of the RF ICD agreement.

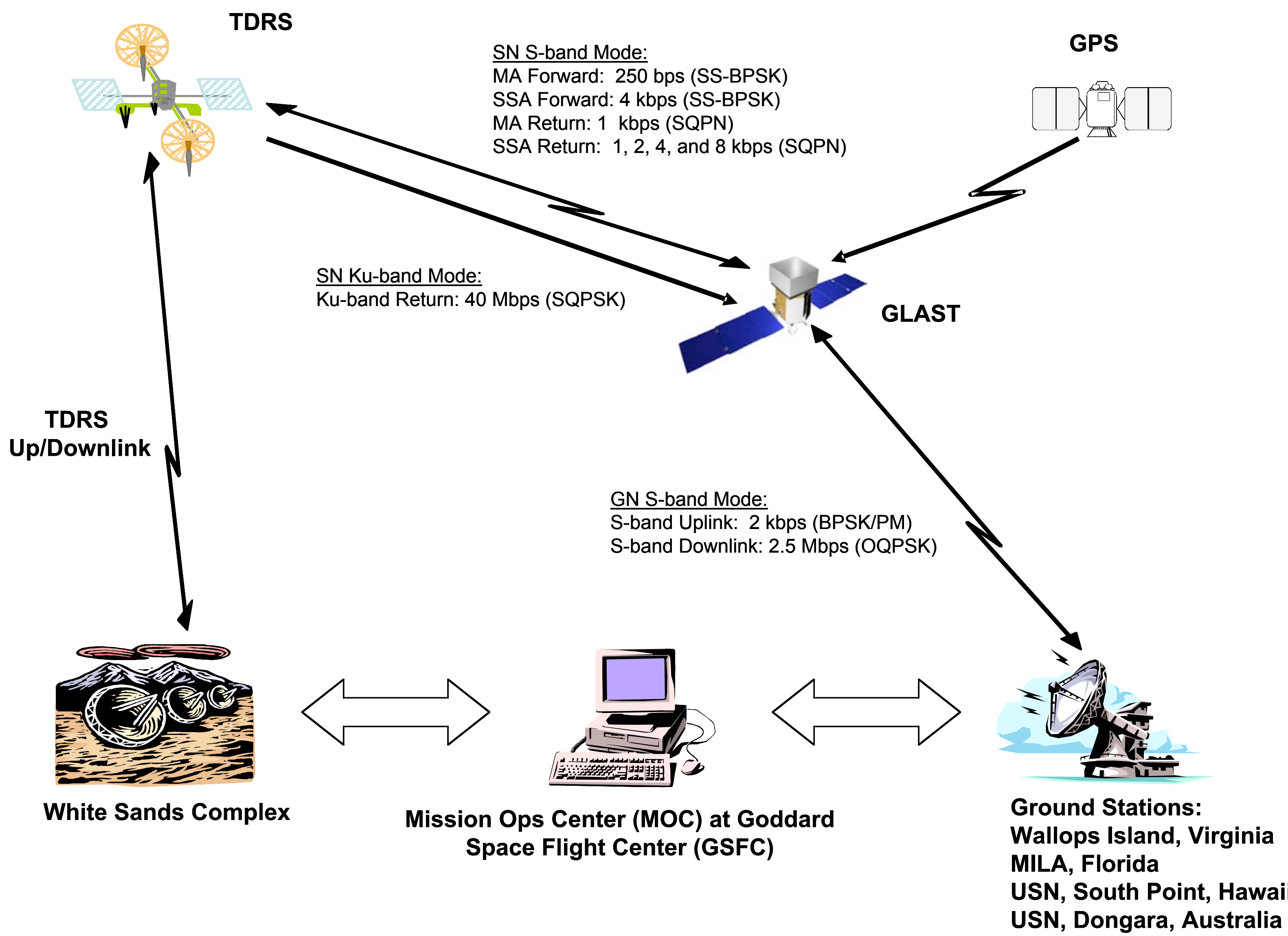


Figure 1-1. GLAST Communication Links

Section 2. Documents

2.1 Applicable Documents

The following documents form a part of this ICD to the extent specified herein. In the event of conflict between this ICD and any other documents invoked herein, the following documents shall govern.

a. Detailed Mission Requirements (DMR) for the GLAST Mission.

b. Project Service Level Agreement (PSLA) for GLAST (TBR).

c. Interface Control Document Between the Demand Access System (DAS) and DAS Customers

1.2 Reference Documents

The following documents are reference documents applicable to the RF interface being controlled. These documents do not form a part of this ICD and are not controlled by their reference herein. In the event of a conflict between this ICD and the following documents, this ICD shall take precedence.

a. *GLAST Phase A Study Report*, TBD.

b. *Requirement of the Ground System for the GLAST Mission,* Revision 1.0.

c. Requirements for the Multi-Mode Transceiver (MMT), With 5 Watt Output, General Dynamics - Decision Systems (GDDS) 12-P55102FJ. (TBR)

d. 450-SNUG, Revision 8, *Space Network (SN) User's Guide*, June 2002.

e. *TDRSS and GSTDN Compatibility Test Van Functional Description and Capabilities*, STDN No. 408, Revision 2, March 1990.

f. 451-PN CODE-SNIP, *Space Network Interoperable PN Code Libraries, Rev 1*, November 1998.

g. 453-GNUG, *Ground Network (GN) Users' Guide*, May 2003.

2.3 Other Related Documents

The following documents are listed for the convenience of the user. These documents do not form a part of this ICD and are not controlled by their reference herein.

a. *Telecommand, Part 1: Channel Service*, Issue 3, Blue Book. Consultative Committee for Space Data Systems, CCSDS 201.0-B-3, June, 2000.

b. *Telecommand, Part 2: Data Routing Service*, Issue 3, Blue Book. Consultative Committee for Space Data Systems, CCSDS 202.0-B-3, June, 2001.

c. *Telecommand, Part 3: Data Management Service,* Issue 2, Blue Book. Consultative Committee for Space Data Systems, CCSDS 203.0-B-1, June 2001.

d. *Telemetry Channel Coding*, Issue 5, Blue Book, Consultative Committee for Space Data Systems, CCSDS 101.0 B-5, June 2001.

e. Recommendation for Space Data Systems Standards Advanced Orbiting Systems, Networks, and Data Links: Architectural Specification. Blue Book,

Consultative Committee for Space Data Systems, CCSDS 701.0-B-3, June 2001.

Section 3. Communications and Tracking Interface Requirements

1.1 General

3.1.1 Interface RF Links

This section defines the required RF communication links:

a. TDRSS-to-GLAST S-band Multiple Access (MA) Forward link.
b. TDRSS-to-GLAST S-band Single Access (SSA) Forward link.
c. GLAST-to-TDRSS S-band Multiple Access (MA) Return link through DAS or MAR legacy service.
d. GLAST-to-TDRSS S-band Single Access (SSA) Return link.
e. GLAST-to-TDRSS Ku-band Single Access (KuSA) Return link
f. GN-to-GLAST S-band Uplink.
g. GLAST-to-GN S-band Downlink.

3.1.2 Interface Functional Applicability

The RF communications interface functional and performance capabilities shall be applicable to the following project phases:

a. RF compatibility testing
b. End-to End (ETE) testing.
c. Pre-Launch: Check-out.
d. Early Orbit Phase: Activation, deployment, initial acquisition, mission orbit insertion. S-band communication links via the hemispherical antennas.
e. On-orbit Verification Phase: Check-out.
f. Normal Operations Phase: Full S-band and Ku-band communication capability.
g. End-of-Mission Phase: S-band communication links.

3.2 Interface Functional Requirements

3.2.1 General

Both the TDRSS and the GN will be used as a means of providing telemetry and command data between the GLAST and the GLAST Mission Operations Center (MOC) at Goddard Space Flight Center. Section 3.2.2 summarizes the GLAST communications subsystem. Sections 3.2.3 and 3.2.4 summarize the communications functional characteristics between the GLAST and TDRSS and between the GLAST and the GN, respectively.

3.2.2 GLAST Communications Subsystem

The GLAST S-band and Ku-band communications subsystem will provide simultaneous transmission and/or reception with the TDRSS and GN ground stations. Figure 3-1 shows GLAST's S-band and Ku-band communications subsystem.

3.2.2.1 GLAST S-band Subsystem Overview

The S-band communications subsystem hardware includes two transceivers (each containing a receiver and a transmitter). A band reject filter and a diplexer are used with each transceiver to attenuate transmitted signal levels in the receive frequency range. In addition, an electro-mechanical transfer switch is used to select between transceivers. Two electronic antenna switches are used to select transmission on the proper hemisphere. Four S-band antennas provide redundant antennas on opposite sides of the Observatory. Transceiver control is achieved using ground commands, or stored commands. The pulse-latched transfer switch is controlled using High Level Discrete (HLD) commands (TBR).

3.2.2.2 GLAST Ku-band Subsystem Overview

The Ku-band communications subsystem hardware includes two transmitters, an electro-mechanical transfer switch for primary/secondary transmitter selection, an Antenna Pointing Assembly (APA), and a high gain antenna. Transmitter control is achieved using ground commands, or stored commands. The pulse-latched transfer switch is controlled using High Level Discrete (HLD) commands (TBR).

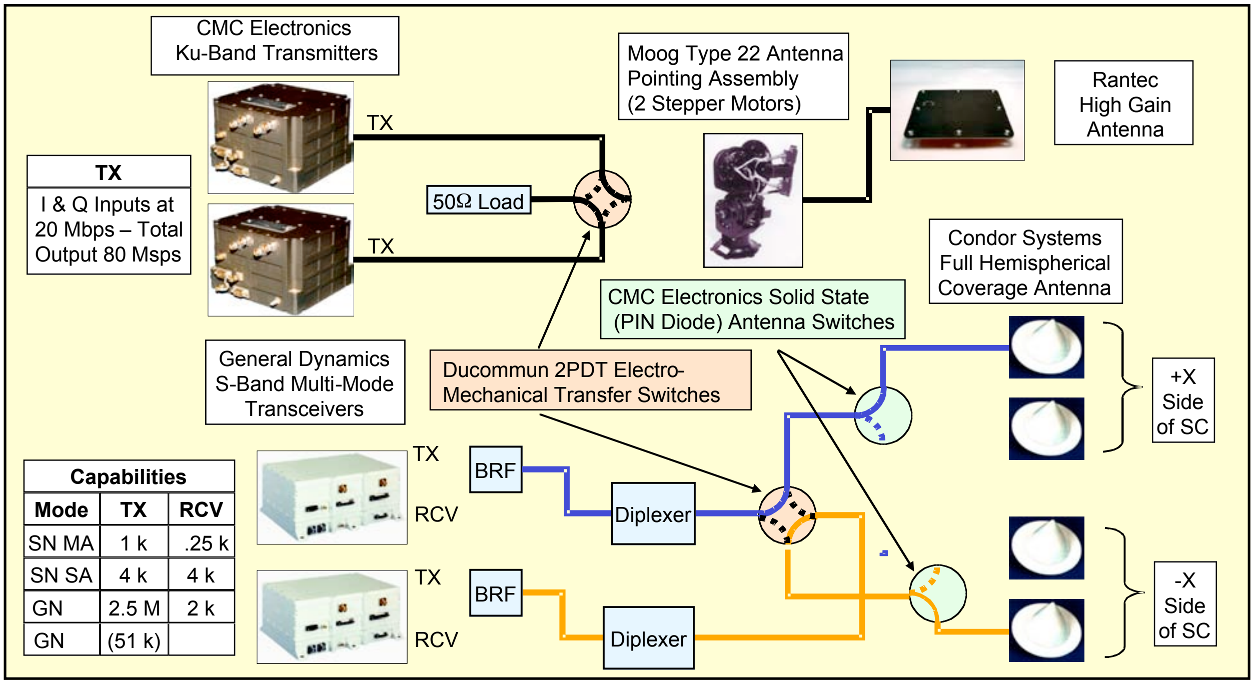
3.2.2.3 Redundancy

The S-band communications subsystem is designed to operate after a single hardware failure in the subsystem for all attitudes of the space vehicle with respect to the SN or GN, except for physical constraints imposed by the location of the GLAST and the TDRS or GN ground stations. The redundant transceivers include receivers that are tied to the Essential Bus (On prior to launch, and On during all phases of the mission). The operation of the redundant transmitters is selectable by uplinked command. There is also total redundancy in the antenna system as well. The switched hemisphere antenna system would require transmit antenna selection if there were a loss of Observatory attitude knowledge.

For normal S-band operations, the selected transceiver transmits through a single hemispherical-coverage antenna. Either transmitter and either antenna (two primary hemispheres) can be selected by ground, or stored commands. Since both receivers are always On, signals are received through two antennas (on opposite sides of the Observatory).

The Ku-band communications subsystem is designed to operate after a single hardware failure in the subsystem for all Observatory attitudes with respect to the SN (except for physical constraints imposed by the location of the GLAST and the TDRS). The operation of the redundant transmitters is selectable by uplinked command. The transmitted signal passes through coaxial rotary joints in the APA, and coaxial cables, to the high gain antenna. The narrow beam antenna is always pointed to a TDRS, using

Observatory attitude input from the GN&C subsystem. Antenna pointing can be changed using ground, or stored commands.



Capabilities		
Mode	**TX**	**RCV**
SN MA	1 k	.25 k
SN SA	4 k	4 k
GN	2.5 M	2 k
GN	(51 k)	

Figure 3-1. GLAST RF Subsystem Block Diagram

GLAST-TDRS **Link Overview**

GLAST TDRSS links provide the functional capabilities listed in paragraphs 3.2.3.1 through 3.2.3.5 when line-of-sight exists and is within the GLAST and TDRS pointing limits.

3.2.3.1 S-band Commands

The TDRSS shall provide for the transmission of digital command data to the GLAST using the S-Band Multiple Access (MA) and Single Access (SSA) forward link service. GLAST command links and data rates are as follows:

- MA Service: 250 bps via Omni antenna
- SSA Service: 4 kbps via Omni antenna

3.2.3.2 S-band Telemetry

Digital telemetry data is transmitted from the GLAST to TDRSS via the MA and the SSA return link service. GLAST telemetry links and data rates are as follows:

- MA Demand Access System (DAS) or MAR Legacy service: 1 kbps via Omni antenna
- SSA Service: 1, 2, 4, and 8 kbps via Omni antenna

3.2.3.3 Ku-band Return Link

Ku-band digital data will be transmitted from the GLAST-to-TDRSS via the KuSA return link service and data rates are as follows:

- KuSA Service: 40 Mbps via High Gain Antenna

3.2.3.4 Range Tracking

TDRSS range tracking support for the GLAST is not required.

3.2.3.5 Doppler Tracking

TDRSS Doppler tracking support for the GLAST is not required. (TBR)

3.2.4 GLAST-GN Link Overview

GLAST-GN S-Band links provide the functional capabilities listed in paragraphs 3.2.4.1 through 3.2.4.4 when line-of-sight exists, the supporting station antenna elevation angle to GLAST is greater than 5 degrees above horizon, and GLAST is above the supporting station local antenna mask.

3.2.4.1 S-band Command

The GN shall provide for the transmission of digital command data to the GLAST via the uplink, using the following command links and data rates:

- GN Uplink: 2 kbps via Omni antenna

3.2.4.2 S-band Telemetry

Digital telemetry data is transmitted from the GLAST to GN via the downlink, using the following telemetry links and data rates:

- GN Downlink: 2.5 Mbps via Omni antenna

3.2.4.3 Range Tracking

No GN range tracking support for the GLAST is required.

3.2.4.4 Doppler Tracking

No GN Doppler tracking support for the GLAST is required.

3.3 Communications Performance Characteristics

3.3.1 General

TDRSS will provide the GLAST with return link data services at a guaranteed Bit Error Rate (BER) of 10^{-5}, if the GLAST meets all of the parameters specified in this ICD and 450-SNUG. TDRSS return link performance is also predicated on the quality of GLAST transmit characteristics as measured against the user constraints defined in Section 4. The controlled parameter on the forward link is the TDRS Effective Isotropic Radiated Power (EIRP). The minimum transmitted TDRS EIRP is the minimum signal EIRP toward the GLAST receiver and includes the transmitter RF signal power, transmitting circuit losses, transmitting antenna gain toward the receiver.

The GN will provide the GLAST with downlink data services at a guaranteed Bit Error Rate (BER) of 10^{-5}, if GLAST meets all of the parameters specified in this ICD and 453-GNUG. The controlled parameter on the uplink is the GN EIRP. The minimum transmitted GN EIRP is the minimum signal EIRP toward the GLAST receiver and includes the transmitter RF signal power, transmitting circuit losses, transmitting antenna gain toward the receiver.

3.3.2 TDRS-to-GLAST Command Channel

The achievement of the GLAST forward link Bit Error Rate (BER) is dependent on the GLAST design and GLAST compatibility with the TDRS EIRP and the forward link signal conditions specified in this ICD and 450-SNUG.

3.3.3 GLAST-to-TDRS Telemetry/Science Channel

The maximum return link information BER for the detected digital data in this telemetry/science channel shall be 10^{-5}, referenced to the output of the differential decoder. This assumes that the return link signal meets all the requirements of section 4. With Reed-Solomon decoding at GLAST MOC, the effective output data BER is expected to be at least 10^{-7} or better.

3.3.4 GN-to-GLAST Command Channel

The achievement of the GLAST uplink Bit Error Rate (BER) is dependent on the GLAST design and GLAST compatibility with the GN EIRP and the uplink signal conditions specified in this ICD and 453-GNUG.

3.3.5 GLAST-to-GN Telemetry Channel

The maximum downlink information BER for the detected digital data in this telemetry/science channel shall be 10^{-5}, referenced to the output of the differential decoder. This assumes that the return link signal meets all the requirements of 453-GNUG. With Reed-Solomon decoding at GLAST MOC, the effective output data BER is expected to be at least 10^{-7} or better.

3.4 GLAST-TDRSS and GLAST-GN Communications Link Modes and Scenarios

GLAST receiving and transmitting communication modes are defined in Table 3-1 and Table 3-2, respectively.

Table 3-1. GLAST Receive Characteristics

Receive Signal Parameters	**S-Band SN**		**S-Band GN**
Service	**MAF**	**SSAF**	**Wallops Island, Virginia** **MILA, Florida (TBD)** **USN, South Point, Hawaii** **USN, Dongara, Australia**
Frequency	2106.40625 MHz	2106.40625 MHz	2106.40625 MHz
User Antenna	Omni	Omni	Omni
Polarization	LHCP	LHCP	LHCP
Data Rate	250 bps	4 kbps	2 kbps
Data Format	NRZ-M	NRZ-M	NRZ-M
Signal Bandwidth	~6 MHz	~6 MHz	~ 36 kHz
PN Chip Rate	3.0778 MHz	3.0778 MHz	N/A
Transmit Modulation	SS-BPSK (Note 1) (TBD)	SS-BPSK (Note 1) (TBD)	BPSK/PM

Notes:

1. The command data is modulo-2 added to the command channel PN code. The composite command signal (PN and command data) phase shift keys the carrier with a modulation index of ±90°. No PN ranging Channel.

Table 3-2. GLAST Transmit Characteristics

Transmit Signal Parameters	S-Band SN		Ku-Band SN	S-Band GN
	MA	**SSA**	**KuSA**	**Wallops Island, Virginia** **MILA, Florida (TBD)** **USN, South Point, Hawaii** **USN, Dongara, Australia**
Data Group	DG1 Mode 2	DG1 Mode 2	DG2 Mode 2	N/A
Transmit Frequency	2287.5 MHz	2287.5 MHz	15003.4 MHz	2287.5 MHz
Polarization	LHCP	LHCP	RHCP	LHCP
User Antenna	Omni	Omni	HGA	Omni
Transmit Power	5.7 Watts	5.7 Watts	10.72 Watts	5.7 Watts
Transmit Data Rate (notes 1)	1 kbps	1, 2, 4, and 8 kbps	40 Mbps	2.5 Mbps
Data Format	NRZ-M	NRZ-M	NRZ-M	NRZ-M
Transmit Modulation	SQPN	SQPN	SQPSK	OQPSK

Notes:

2. The data rates included in this table are the data rates prior to any convolutional coding. The GLAST transmit data rates in this table include RS overhead, where applicable.

Section 4. TDRSS Link Interface Characteristics

4.1 Introduction

This section specifies the functional design of each RF link. Pertinent GLAST, TDRSS, and GN communications signal designs and system performance requirements are also specified.

4.2 Link Functional Designs

4.2.1 TDRSS-to-GLAST MA Forward Link

4.2.1.1 General

TDRSS-to-GLAST forward link service is available on a scheduled basis during intervals that TDRS-GLAST line-of-sight exists. The signal characteristics of the MA forward link shall be in accordance with those shown for the forward configurations in Table 4-1.

4.2.1.2 Link Description

a. The MA link shall be used to provide command data to the GLAST at a data rate of 250 bps. The functional interface of this link shall be as shown in Figure 4-1.

b. For the MA forward, command data in the Non-Return to Zero-Mark (NRZ-M) format shall be provided at the WSC interface. The command data shall be modulo-2 added asynchronously to the command channel PN code, with the resulting spread-spectrum coded sequence modulating the I channel of a Phase-Shift Keying PSK transmitter at a rate of 3.0778 Mchip/sec, synthesized from the forward link carrier frequency. For command link, the TDRSS will be configured to disable the ranging channel; therefore, all the power will be on the I-channel.

c. The TDRS transmitter will operate at Left-Hand Circular Polarization (LHCP) with a nominal frequency of 2106.40625 MHz towards the GLAST.

d. The GLAST Platform will utilize a spread-spectrum psuedorandom noise (PN) receiver to despread the I channel command data signal and pass the resulting despread command data signal to the BPSK demodulator and bit synchronizer.

4.2.2 TDRSS-to-GLAST SSA Forward Link

The SSA forward link functional configuration is similar to the MA forward link defined in paragraph 4.2.1, Table 4-1, and shown in Figure 4-1, with the following exception: GLAST has selected command data rates of 4 kbps on the SSA forward link.

4.2.3 GLAST-to-TDRSS MA Return Link

4.2.3.1 General

GLAST-to-TDRSS return link service is available on a scheduled basis during intervals that TDRS-GLAST line-of-sight exists. The MAR DAS or legacy link is operated in non-coherent mode. The signal parameters of the MA return link shall be in accordance with those shown in Table 4-2. The functional interface of this link shall be as shown in Figure 4-2.

4.2.3.2 Link Description

a. The MA link shall be utilized to send telemetry data from the GLAST to TDRSS. A GLAST omni antenna will be used to transmit a total data rate of 1 kbps.

b. For this link, a 1 kbps data stream will be differentially encoded into NRZ-M and then sent to a rate 1/2 convolutional encoder. The encoded symbols, at a rate of 2 ksps, will be provided to both the I and Q channel. Thus, the I and Q channels will contain identical data. Each 2 ksps channel will be modulo-2 added asynchronously to a PN code. The I & Q channel PN codes will be offset by 1/2 of a chip period. The two resulting spread-spectrum coded sequences will be input into the balanced power (1:1) QPSK Modulator which will yield a Staggered Quadriphase Pseudorandom Noise (SQPN) signal at the output of the QPSK modulator.

c. For the return link non-coherent mode 2, the I and Q channel codes are short Gold codes. Mode 2 is used when return link operation (or acquisition) is required without the need for prior forward link acquisition and tracking and for all DAS services. During mode 2, an on board reference oscillator will be used to generate the transmit carrier.

d. The SQPN-modulated return link signal is transmitted at 2287.5 MHz to the TDRS through a Left-Hand Circular (LHC) polarized omni antenna.

e. For this link, the TDRSS ground terminal utilizes both the I and Q channels from the TDRS. The WSC utilizes a spread-spectrum pseudo-random noise (PN) receiver to acquire, track, despread, and demodulate the I channel and Q channel portions of the spread spectrum signal. The I and Q channels are combined through a predetection combiner. For the GLAST single data source configuration, the SN ground terminal uses predetection combining to provide 3 dB superior signal-to-noise ratio into the carrier and symbol tracking loops. The despread channels are processed by bit synchronizers, which recover the symbol clock and provide the encoded symbols to a Viterbi decoder (rate 1/2, constraint length 7). The resulting 1 kbps NRZ-L data is provided at the output of the WSC.

4.2.4 GLAST-to-TDRSS SSA Return Link

4.2.4.1 General

GLAST-to-TDRSS return link service is available on a scheduled basis during intervals that TDRS-GLAST line-of-sight exists. The SSAR link is operated in PN spread non-coherent mode known as DG1 Mode 2. The signal parameters of the SSA return link shall be in accordance with those shown in Table 4-2. The functional interface of this link shall be as shown in Figure 4-3.

4.2.4.2 Link Description

a. The SSA link shall be utilized to send telemetry data from the GLAST to TDRSS. A GLAST omni antenna will be used to transmit a total data rate of 1, 2, 4, and 8 kbps.

b. For this link, data steams in NRZ-L data format will be RS encoded. The NRZ-L data will be differentially encoded into NRZ-M and then sent to a rate 1/2 convolutional encoder. The encoded symbols will be provided to both the I and Q channel. Thus, the I and Q channels will contain identical data. Each channel will be modulo-2 added asynchronously to a PN code. The I & Q channel PN codes will be offset by 1/2 of a chip period. The two resulting spread-spectrum coded sequences will be input into the balanced power (1:1) QPSK Modulator which will yield a Staggered Quadriphase Pseudorandom Noise (SQPN) signal at the output of the QPSK modulator

c. For the return link non-coherent mode 2, the I and Q channel codes are short Gold codes. Mode 2 is used when return link operation (or acquisition) is required without the need for prior forward link acquisition and tracking. During mode 2, an on board reference oscillator will be used to generate the transmit carrier.

d. The SQPN-modulated return link signal is transmitted at 2287.5 MHz to the TDRS through the Left-Hand Circular (LHC) polarized Omni antenna.

e. For this link, the TDRSS ground terminal utilizes both the I and Q channels from the TDRS. The WSC utilizes a spread-spectrum pseudo-random noise (PN) receiver to acquire, track, despread, and demodulate the I channel and Q channel portions of the spread spectrum signal. The I and Q channels are combined through a predetection combiner. For the GLAST single data source configuration, the SN ground terminal uses predetection combining to provide 3 dB superior signal-to-noise ratio into the carrier and symbol tracking loops. The despread channels are processed by bit synchronizers, which recover the symbol clock and provide the encoded symbols to a Viterbi decoder (rate 1/2, constraint length 7). The resulting NRZ-L data is provided at the output of the WSC. The GLAST ground segment will perform RS decoding.

Table 4-1. TDRSS-to-GLAST MA and SSA Forward Link Parameters

Parameter	Value
TDRS transmit carrier frequency	F (nominally 2106.40625 MHz)
Carrier frequency arriving at GLAST	F_R (note 1)
Carrier frequency sweep (note 3)	$\pm$3 kHz
Carrier frequency sweep duration (note 3)	120 seconds
Command Channel (I-channel)	
Carrier frequency	F
PN modulation	PSK, $\pm \pi/2$ modulation
Carrier suppression	30 dB minimum
PN code length	$2^{10} - 1$ chips
PN code assignment	NASA # 36
PN code family	Gold codes
PN chip rate	(31/21216) x F (nominal 3.0778 Mcps)
Data modulation	Modulo-2 added asynchronously to PN Code
Data format	NRZ-M (transparent to TDRSS)
Data rate (note 2)	250 bps through MA 4 kbps through SSA

NOTES:

1. Doppler compensation will be available for $\dot{R} \le 12$ km/sec. During periods of Doppler compensation, $F_R = f_o \pm E$ Hz; where f_o = nominal center frequency of the GLAST receiver as defined by the GLAST MOC and E = (70 x $\dot{R}$); $\ddot{R} \le 15$ m/sec^2. During periods of Doppler compensation inhibit, the SN/GN will round-off the customer receive frequency contained in the SHO to the nearest multiple of 221 Hz, which will result in an additional frequency error of up to 110 Hz. If Doppler compensation is inhibited after the start of the forward service, a transition profile will be initiated to slowly change the frequency from the compensate profile to this integer multiple of 221 Hz.
   Forward service Doppler compensation will not increase the effective frequency rate of change seen at the customer receiver more than 28 Hz/sec relative to the frequency for a Doppler-free carrier.
2. The forward data rate is the data rate prior to any data formatting or convolutional coding. The symbol rate is the baud rate that is received at the SN interface and includes all data formatting and convolutional coding. Data formatting and convolutional coding is transparent to the SN and must be done prior to the SN interface.
3. After the start of the S-Band forward or uplink service, if a customer MOC is unable to accurately define f_o (the nominal center frequency of the customer platform receiver), the forward service carrier frequency can be swept. The S-Band forward service frequency sweep will be initiated by the SN at f_o-3 kHz and linearly swept to f_o+3 kHz in 120 seconds and held at f_o+3 kHz thereafter. The S-Band forward service frequency sweep does not impact simultaneous WSC Doppler compensation of the forward service carrier and PN code rate (if applicable).

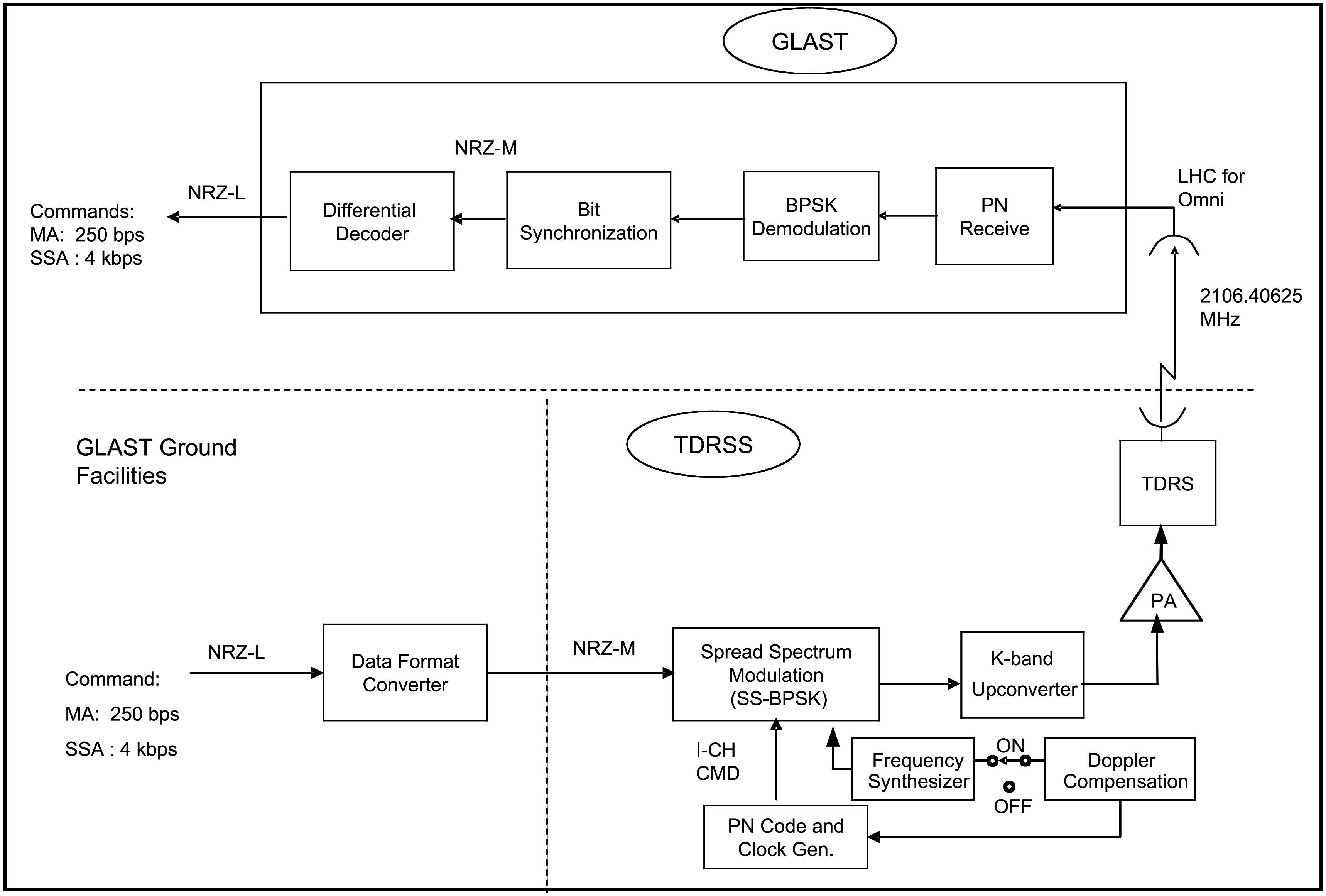


Figure 4-1. TDRSS-to-GLAST MA or SSA Forward Link Functional Configuration

Table 4-2. GLAST-to-TDRSS MA and SSA Return Link Signal Parameters

Parameter	Value
Transmit carrier frequency (note 1)	GLAST transmitter oscillator (nominally F_1 = 2287.5 MHz)
Data Configuration	Single Data Source, Identical Data on I and Q channels
Data group and mode	DG1 Mode 2 (non coherent)
PN Modulation	SQPN
PN code chip rate	F_1 x 31/(240x96) chips/sec (nominally = 3.08 Mcps)
PN code length	$2^{11} – 1$ chips
PN code family	Gold codes
PN code Assignment	NASA #36
Data format	NRZ-M
Symbol format	NRZ
Antenna	LHCP (Omni)
Data rate (note 2)	1 kbps through MA 1, 2, 4, and 8 kbps through SSA
Data encoding	Rate _ for MA Rate _ and Reed Solomon encoding (223,255) for SSA

NOTES:
1. Noncoherent configurations require a customer transmit frequency uncertainty of ± 700 Hz. If a customer cannot accurately define their transmit frequency to within ± 700 Hz, a customer can request a reconfiguration which would expand the oscillator frequency search to ± 3 kHz after the start of service.
2. The data rate included in this table is the data rate prior to any convolutional coding. The GLAST transmit data rate includes RS coding overhead when applicable.

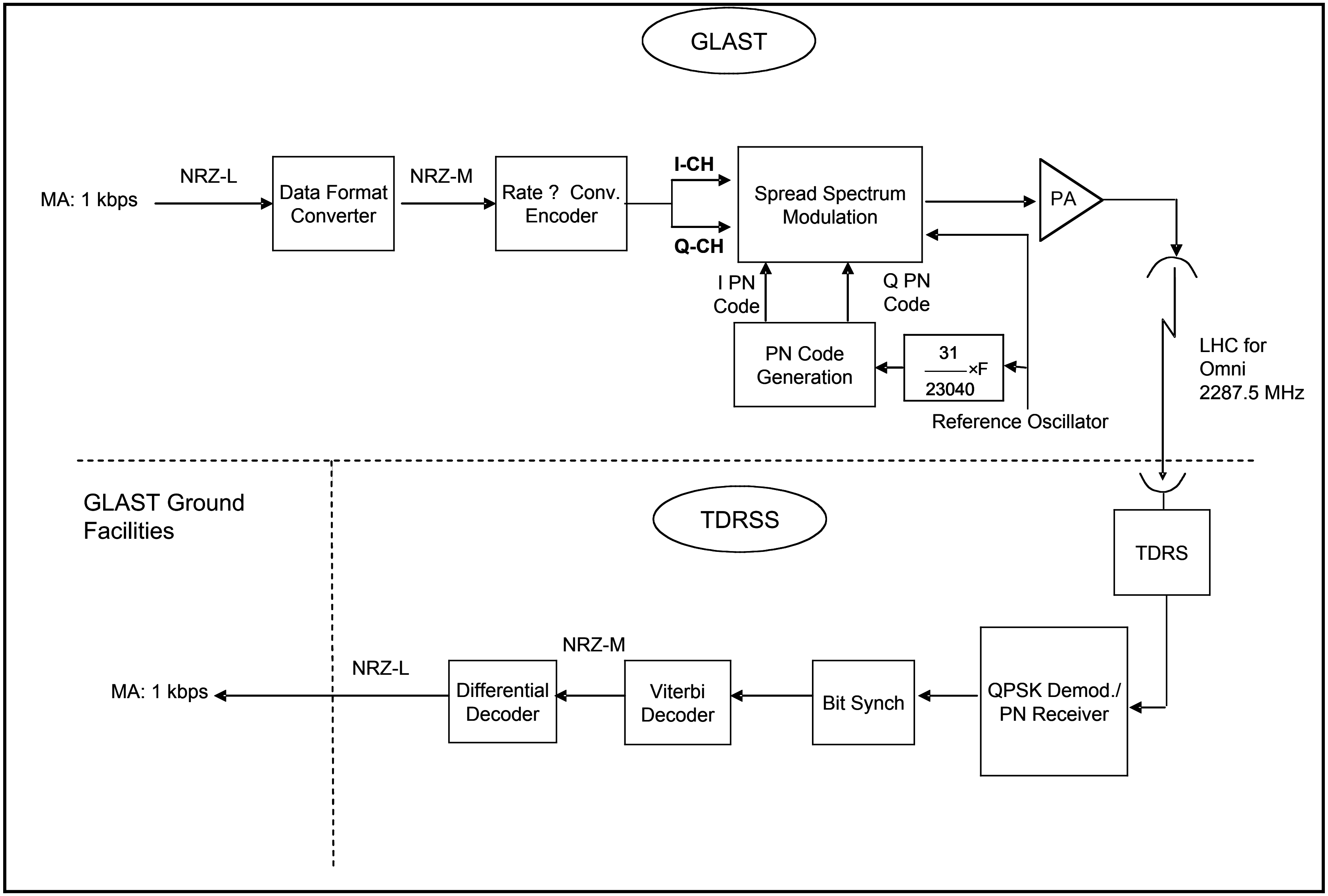


Figure 4-2. GLAST-to-TDRSS MA DG1 Mode 2Return Link Functional Configuration

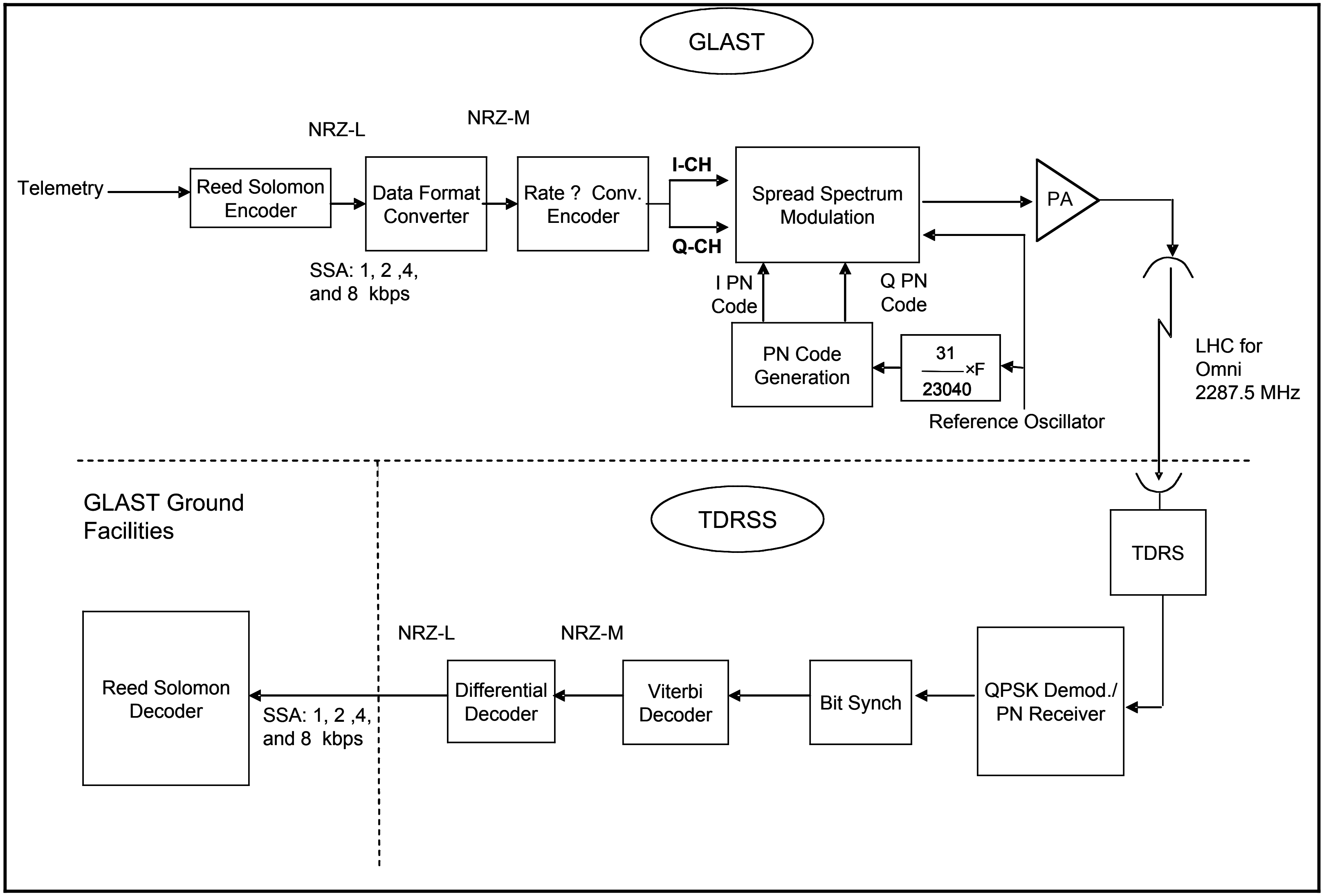


Figure 4-3. GLAST-to-TDRSS SSA DG1 Mode 2 Return Link Functional Configuration

4.2.5 GLAST-to-TDRSS Ku-band Return Link

4.2.5.1 General

GLAST-to-TDRSS return link service is available on a scheduled basis during intervals that TDRS-GLAST line-of-sight exists. The KuSAR link is operated in unspread non-coherent mode known as DG2 Mode 2. The signal parameters of the KuSA return link shall be in accordance with those shown in Table 4-3. The functional interface of this link shall be as shown in Figure 4-4.

4.2.5.2 Link Description

a. The KuSA link shall be utilized to send science and telemetry data from the GLAST to TDRSS. The GLAST HGA will be used to transmit a total data rate of 40 Mbps, where the information rate is 34.98 Mbps prior to (223,255) RS encoding.

b. For the DG2 Mode 2 KuSA return link, the 34.98 Mbps NRZ-L information stream will be RS encoded to 40 Mbps prior to splitting the stream into an I-channel and Q-Channel, where the 40 Mbps data is alternated between the I and Q channels. Each channel will have a data rate of 20 Mbps. The NRZ-L data of each channel will then be individually differentially encoded into NRZ-M. The I and Q channels will be individually rate _ convolutionally encoded, where each channel will have 2 branch rate _ encoders. The composite serial symbol output on each channel will consist of the branch encoder output symbols interleaved every 2nd symbol (i.e., encoder 1 output, encoder 2 output, encoder 1 output, encoder 2 output,…). Due to alternating the bits on the I and Q channels, the channels will be offset by _ symbol before QPSK modulation. The resulting Staggered Quadriphase Shift Keying (SQPSK) modulated signal will be transmitted to TDRSS with an I/Q channel power ratio of 1:1.

c. The SQPSK modulated return link signal is transmitted at 15003.4 MHz to the TDRS through the Right Hand Circular Polarization (RHCP) HGA.

d. For this link, the TDRSS ground terminal will SQPSK demodulate the signal. The I and Q channels will then be delivered to the bit synchronizers and Viterbi decoders. Data clock recovery and NRZ-M signals will be delivered to the differential decoders, which will convert the data format to NRZ-L. The two NRZ-L channels will be combined by a multiplexer into the 40 Mbps NRZ-L data stream that will be sent from the WSC to the GLAST Ground Segment. The GLAST ground segment will perform RS decoding.

Table 4-3. GLAST-to-TDRSS KuSA Return Link Signal Parameters

Parameter	Value
TDRS transmit carrier frequency (notes 1 and 2)	GLAST transmitter oscillator (nominally F_1 = 15003.4 MHz)
Data group and mode	DG2 non-coherent
Data configuration	Single data source with alternate I/Q data bits
I/Q power ratio	1:1
Data modulation	SQPSK
Data format	NRZ-M
Symbol format	NRZ
Data rate (note 3)	40 Mbps
Data encoding	Rate _ and Reed Solomon encoding (223,255)

NOTES:

1. Center frequency, fo, of the customer platform transmitter must be define by the customer MOC in its service specification code to an integral multiple of 10 Hz.
2. Noncoherent configurations require a customer transmit frequency uncertainty of $\pm$5 kHz. If a customer cannot accurately define their transmit frequency to within $\pm$5 kHz, a customer can request a reconfiguration which would expand the oscillator frequency to $\pm$20 kHz after the start of service.
3. The data rate included in this table is the data rate prior to any convolutional coding. The GLAST transmit data rate includes RS coding overhead.

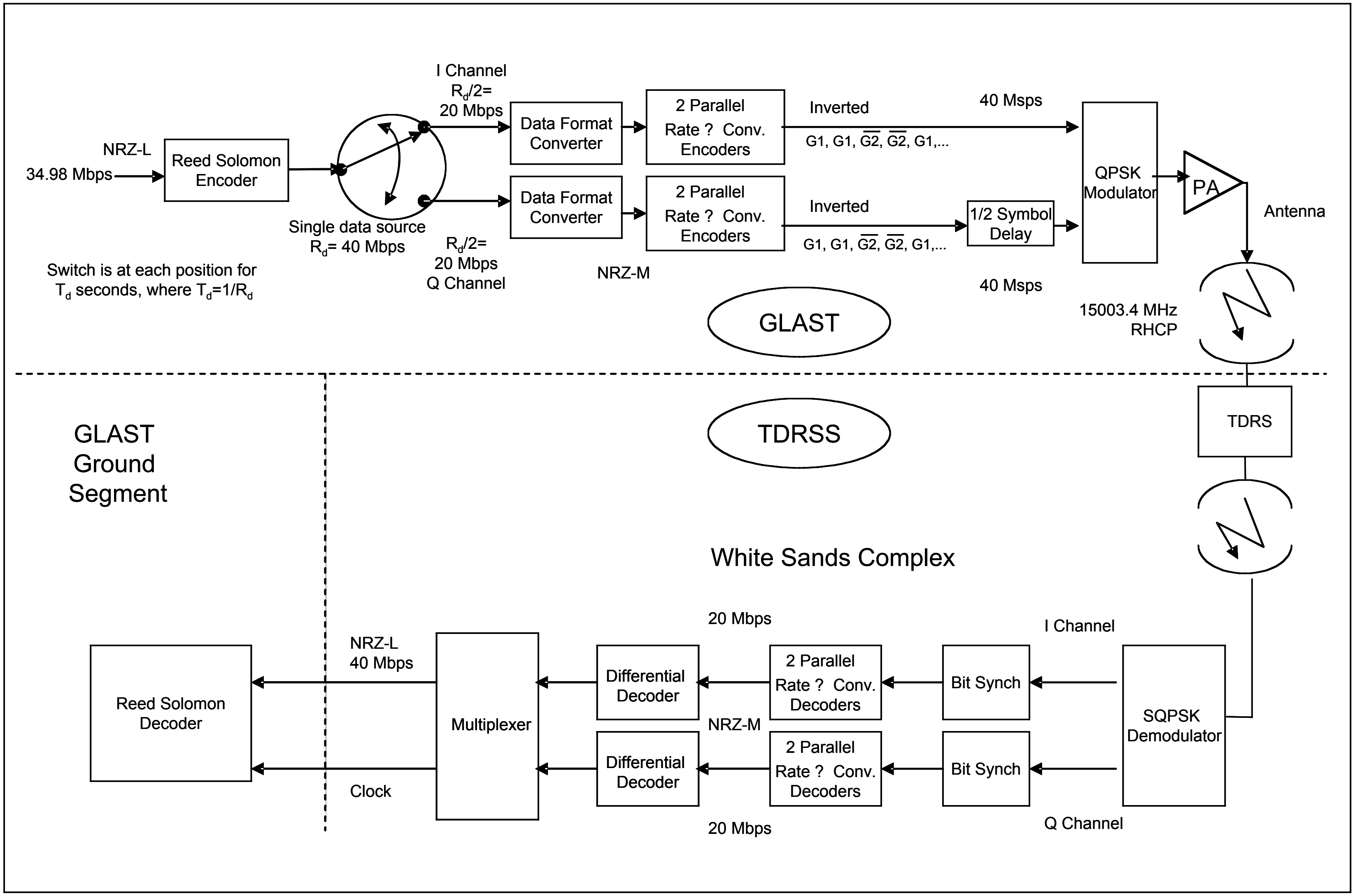


Figure 4-4. GLAST-to-TDRSS KuSA DG2 Mode 2 Return Link Functional Configuration

4.2.6 GN-to-GLAST Uplink

4.2.6.1 General

The GN-to-GLAST uplink service is available on a scheduled basis during intervals that GN-GLAST line of sight exists, the supporting station antenna elevation angle to GLAST is greater than 5 degrees above horizon, and GLAST is above the supporting station local antenna mask. This link contains a command channel only. The signal characteristics of the GN and uplinks shall be in accordance with Table 4-4. The functional interface of this link is shown in Figure 4-5.

4.2.6.2 Link Description

a. The commands originating at the GLAST Mission Operations Center (MOC) are encoded into NRZ-M format at the rate of 2 kbps. The subcarrier modulator of the GN ground stations generates a subcarrier frequency of 16 kHz. The formatted command is used to BPSK modulate the 16 kHz subcarrier. The transmitter operates at a frequency of 2106.40625 MHz.

b. The uplink signal is received at the Observatory, via the S-Band Omni antenna, where the PM signal is demodulated to provide the baseband signal. The 16 kHz baseband subcarrier signal is then BPSK demodulated and passed to the Command and Data Handling (C&DH) subsystem, from which the command data in the NRZ-M format, and a 2 kHz command clock, will be detected and supplied for command processing.

4.2.7 GLAST-to-GN Downlink

4.2.7.1 General

GLAST-to-GN downlink service is available on a scheduled basis during intervals that GN-GLAST line-of-sight exists, the supporting station antenna elevation angle to GLAST is greater than 5 degrees above horizon, and GLAST is above the supporting station local antenna mask. The signal characteristics of the GN downlinks shall be in accordance with Table 4-5. The functional interface of this link shall be as shown in Figure 4-6.

4.2.7.2 Link Description

a. The downlink data rate is 2.5 Mbps (including RS encoding) NRZ-L data. After RS encoding, the NRZ-L data will be differentially encoded into NRZ-M. The NRZ-M data stream will be rate _ convolutionally encoded to 5 Msps. The encoded symbols will be alternated onto the I and Q channels, where the I channel will contain the G1 output of the convolutionally encoded stream at a rate of 2.5 Msps and the Q channel will contain the G2 output of the convolutionally coded stream at a rate of 2.5 Msps.

b. Due to the alternating symbols on the I and Q channels, the channels will be offset by _ symbol before QPSK modulation. The OQPSK modulation will be applied with an I:Q power ratio of 1:1. The transceiver shall maintain the return transmit frequency at a nominal value of 2287.5 MHz.

c. This link shall employ the Left Hand Circularly Polarized (LHCP) Omni, for transmitting the signal to the ground station.

d. The GN ground station receiver provides both the I and Q channels to the OQPSK demodulator. The I and Q channels will then be delivered to the bit synchronizers and Viterbi decoder. The Viterbi decoder will resolve I and Q channels and result in a single data stream. Data clock recovery and NRZ-M signal will be delivered to the differential decoder, which will convert the data format to NRZ-L. The 2.5 Mbps NRZ-L data stream will be sent from the GN to the GLAST Ground Segment. The GLAST ground segment will perform RS decoding.

Table 4-4. S-Band Uplink Signal Parameters to GLAST

Interface Characteristic	GN Uplink Characterization
Ground Stations	11.3-m Wallops Island, Virginia 9-m MILA, Florida (TBD) 13-m USN, South Point, Hawaii 13-m USN, Dongara, Australia
Frequency	2106.4 MHz
Modulation	BPSK/PM
Subcarrier Frequency	16 kHz
Modulation Index	1.0 radian
Data Rate	2 kbps
Symbol Rate	2 ksps
Data Format	NRZ-M

Table 4-5. S-Band Downlink Signal Parameters from GLAST

Interface Characteristic	GN Downlink Characterization
Ground Stations	11.3-m Wallops Island, Virginia 9-m MILA, Florida (TBD) 13-m USN, South Point, Hawaii 13-m USN, Dongara, Australia
Data source	Single Data Source with Alternate I/Q symbols
Frequency	2287.5 MHz
Modulation	OQPSK
Data Format	NRZ-M
Data Type	Telemetry
Data Rate (notes 1)	2.5 Mbps
Coding	Rate _ and Reed Solomon (223,255)
NOTES: 1. The data rate included in this table is the data rate prior to any convolutional coding. The GLAST transmit data rate includes RS coding overhead.	

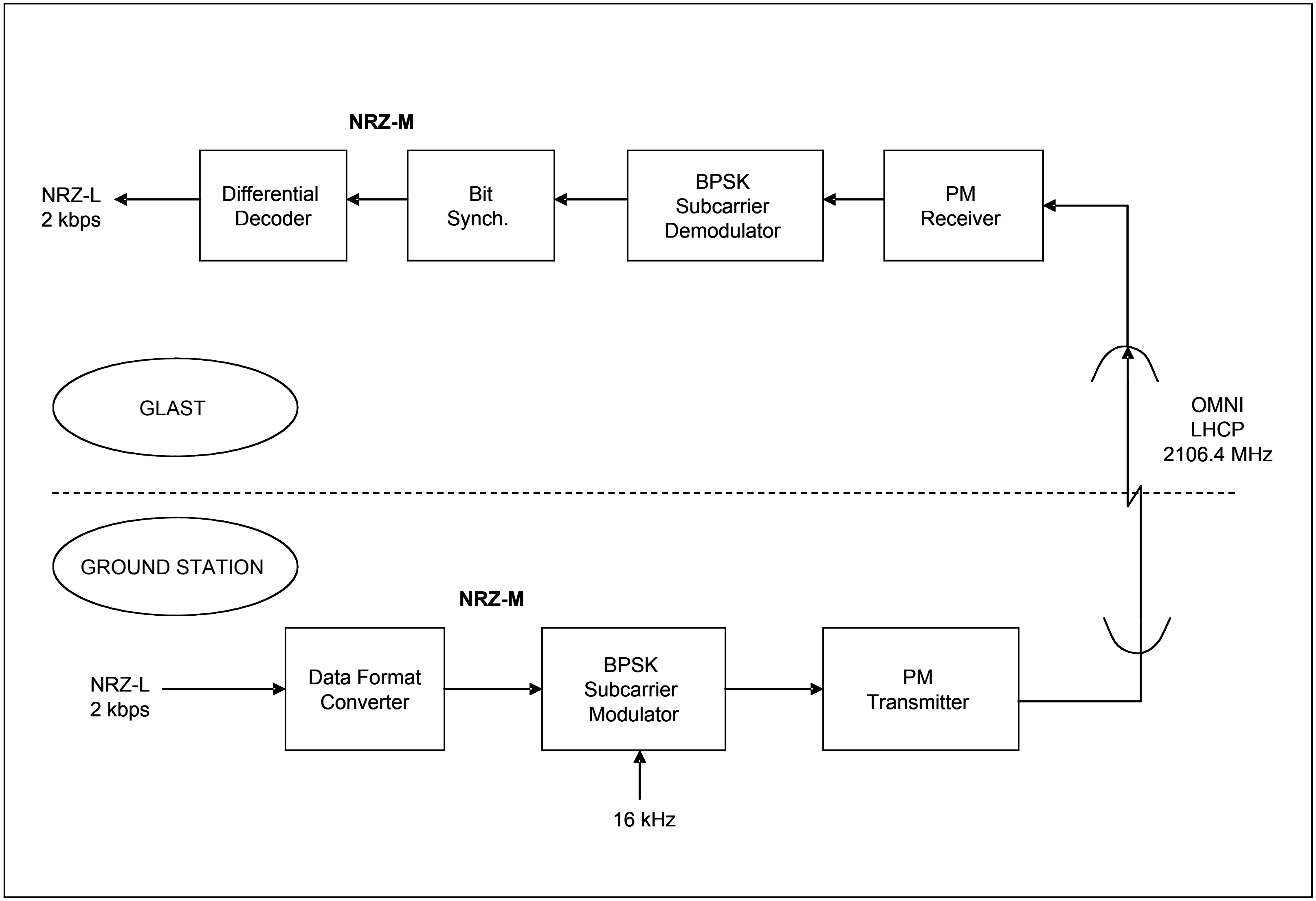


Figure 4-5. GN-to-GLAST Uplink Configuration

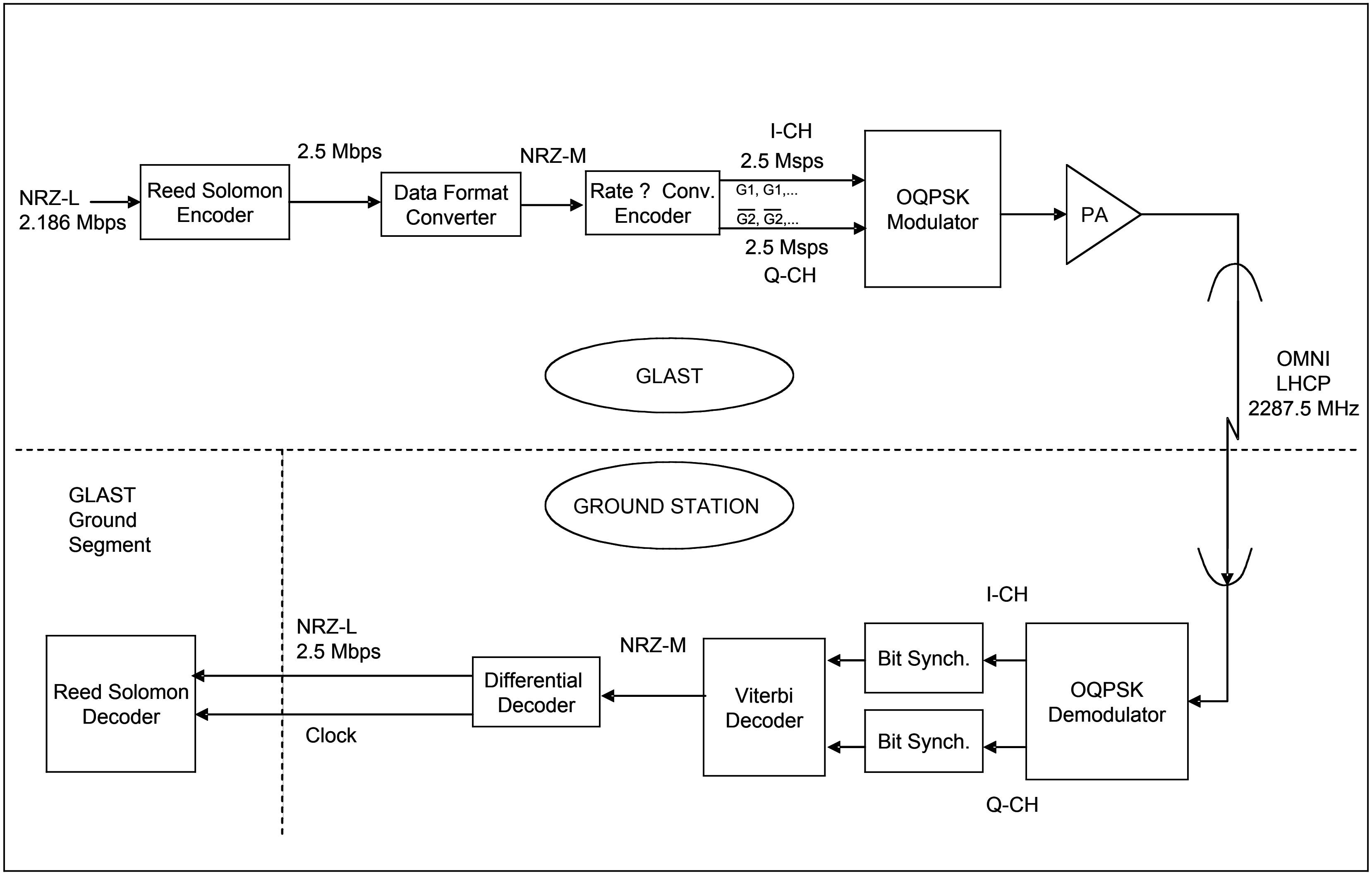


Figure 4-6. GLAST-to-GN Downlink Configuration

4.3 Baseband Signal Descriptions

1.1.1 Purpose

Paragraph 4.3 describes baseband signal processing in the TDRSS, GLAST mission ground segment, the GN stations, and the baseband signal parameters which affect the performance of the RF link.

4.3.2 S-band Forward/Uplink Baseband Characteristics

For all configurations, the GLAST ground segment formats the data to NRZ-M prior to receipt at the SN/GN. The coding and formatting is transparent to SN/GN. The spacecraft will be operated in a non-coherent mode. The GLAST uplink system will consist of a 16 kHz subcarrier of an S-band 2106.4 MHz carrier.

4.3.3 Command Data Format (TBR)

The input data format to GLAST will be in the form of a CCSDS Command Link Transmission Unit (CLTU). The CLTU is a data structure that carries the telecommand data as a contiguous series of encoded telecommand Codeblocks across the data channel.

4.3.3.1 Command Link Transmission Unit (CLTU)

The Command Link Transmission Unit (CLTU), as illustrated in Figure 4-7, shall comprise a 16-bit CLTU start sequence, an Encoded TC Data field, and a 64-bit CLTU tail sequence. The CLTU length shall be constrained to be no greater than 306 bytes.

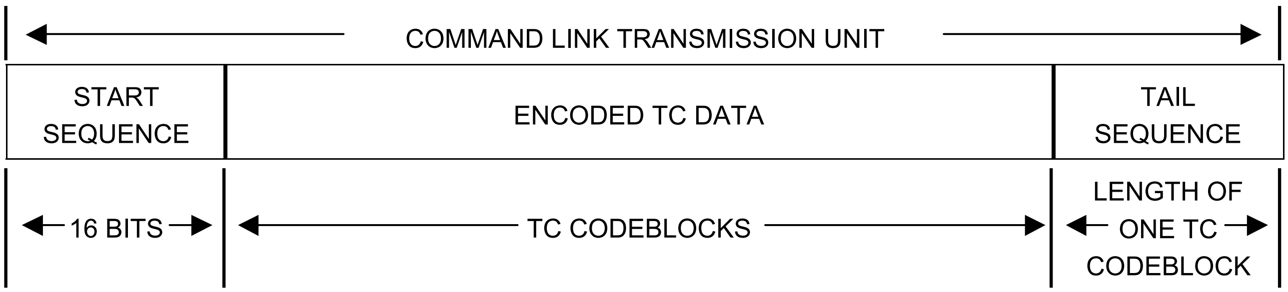


Figure 4-7. Components of the Command Link Transmission Unit (CLTU)

4.3.3.2 4.3.3.1.2 CLTU Start Sequence

The CLTU start sequence shall be set to the following pattern (hexadecimal value 0xEB90):

Bit #	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Bit Value	1	1	1	0	1	0	1	1	1	0	0	1	0	0	0	0

4.3.3.3 Encoded TC Data Field

The Encoded TC data field consists of one or more 64-bit TC Codeblocks that have been encoded in accordance with the TC Codeblock encoding procedure. The number of codeblocks depends on the length of the TC being transferred. Each codeblock will be composed of seven bytes of TC data followed by one byte of error control bits. The last codeblock may contain fill bytes (of any value) to fill out the seven bytes of TC data. The TC data shall consist of exactly one telecommand transfer frame.

4.3.3.4 Tail Sequence

The CLTU tail sequence field is a data structure that is constructed specifically to be a non-correctable sequence that delimits the end of a CLTU. The tail sequence will have the following pattern: 0xC5C5C5C5C5C5C579.

4.3.4 S-band Return/Down Link Baseband Characteristics

The S-Band telemetry consists of a single data source of NRZ-L data. The source is RS encoded (except for MAR) and then NRZ-M formatted. For the return links through the SN, the NRZ-M data stream is rate 1/2 convolutionally encoded and the symbols are identically applied to both the I and Q channels. For the downlink through the GN, the NRZ-M data stream is rate _ convolutionally encoded and the output symbols are alternately applied to the I and Q channels. NRZ-L formatted data will be provided at the output of the SN/GN. The format for NRZ-M and NRZ-L data shall conform to that shown in Figure 4-10.

4.3.5 Ku-band Return Link Baseband Characteristics

The Ku-Band telemetry/science data consists of a single data source of NRZ-L data. The source is RS encoded and then split into I and Q channels by alternating the bits on each channel. Each channel data stream is individually NRZ-M formatted. The I and Q channels will be individually rate _ convolutionally encoded, where each channel will have 2 branch rate _ encoders. The composite serial symbol output on each channel will consist of the branch encoder output symbols interleaved every 2nd symbol (i.e., encoder 1 output, encoder 2 output, encoder 1 output, encoder 2 output,…). A single data stream of NRZ-L formatted data will be provided at the output of the SN. The format for NRZ-M and NRZ-L data shall conform to that shown in Figure 4-10.

4.3.6 Telemetry Formats (TBR)

4.3.6.1 General

All Observatory data transmitted over the S-band SSA, and Ku-band return links will be sent as a class of data delivery service equivalent to Grade 2 service, defined in *Advanced Orbiting Systems, Networks and Data Links: Architectural Specification,* CCSDS 701.0-B-3, and presented in the *GLAST Observatory to Ground Interface Control Document.* Observatory data transmitted over the S-Band MA does not use Grade 2 service. The goal is to have a BER of 10^{-5} for the final processed data at the GLAST Mission Operation Center. TDRSS will provide a 10^{-5} BER at the output of the White Sands Complex (WSC) differential decoder interface.

4.3.6.2 Data and Symbol Signal Formats

a. The telemetry/science data signal output is in the NRZ-M signal format prior to convolutional coding in the S-band and in the Ku-band cases.

b. The telemetry format from the GLAST Observatory will be in the form of a Consultative Committee for Space Data Systems (CCSDS) Advanced Orbiting Systems (AOS) Virtual Channel Data Unit (VCDU). The VCDU is the data structure that provides fixed-length, byte-aligned data blocks used for transmitting data from the S/C to the ground.

c. The GLAST Observatory has two S-band Multi-Mode Transceivers (MMT). Although a CCSDS AOS VCDU is downlinked to both the TDRS MA and the TDRS SSA, each uses different encoding methods. The TDRS MA return link will use convolutional encoding, but won't use Reed-Solomon encoding. The TDRS SSA return link will use both convolutional encoding and Reed-Solomon encoding. The GLAST Observatory Ku-band transmitter will use both convolutional encoding and Reed-Solomon encoding.

d. The VCDU has the structural components as illustrated in Figure 4-8. The following is an abbreviated description of the VCDU as it pertains to the GLAST mission and the Observatory. A complete description of the VCDU can be referenced in *CCSDS Advanced Orbiting Systems, Networks and Data Links, Architectural Specification*, paragraph 5.4.9.2.1.

e. Figure 4-9 shows the VCDU format for SN/GN links.

f. The TDRS Ku-band link uses Virtual Channels 0, 1, 2, 3, 8, 9 and 63, and will use the Coded Virtual Channel Data Unit (CVCDU) Reed-Solomon Check symbols. The TDRS Ku-band link will not use the VCDU Error Control Field.

The length of the entire fixed length CVCDU is 10200 bits (1275 bytes), which is preceded by a 32-bit Synchronization Field.

g. The TDRS S-band SA link uses Virtual Channels 10 and 63, and also uses the Coded Virtual Channel Data Unit (CVCDU) Reed-Solomon Check Symbols. The TDRS S-band SA link will not use the VCDU Error Control Field. The length of the entire fixed length CVCDU is 10200 bits (1275 bytes), which is preceded by a 32-bit Synchronization Field.

h. The TDRS S-band MA link uses Virtual Channels 11 and 63, and will use convolutional encoding. The TDRSS S-band MA link will use the VCDU Error Control Field. The length of its entire fixed length VCDU is 992 bits (124 bytes), which is preceded by a 32-bit Synchronization Field.

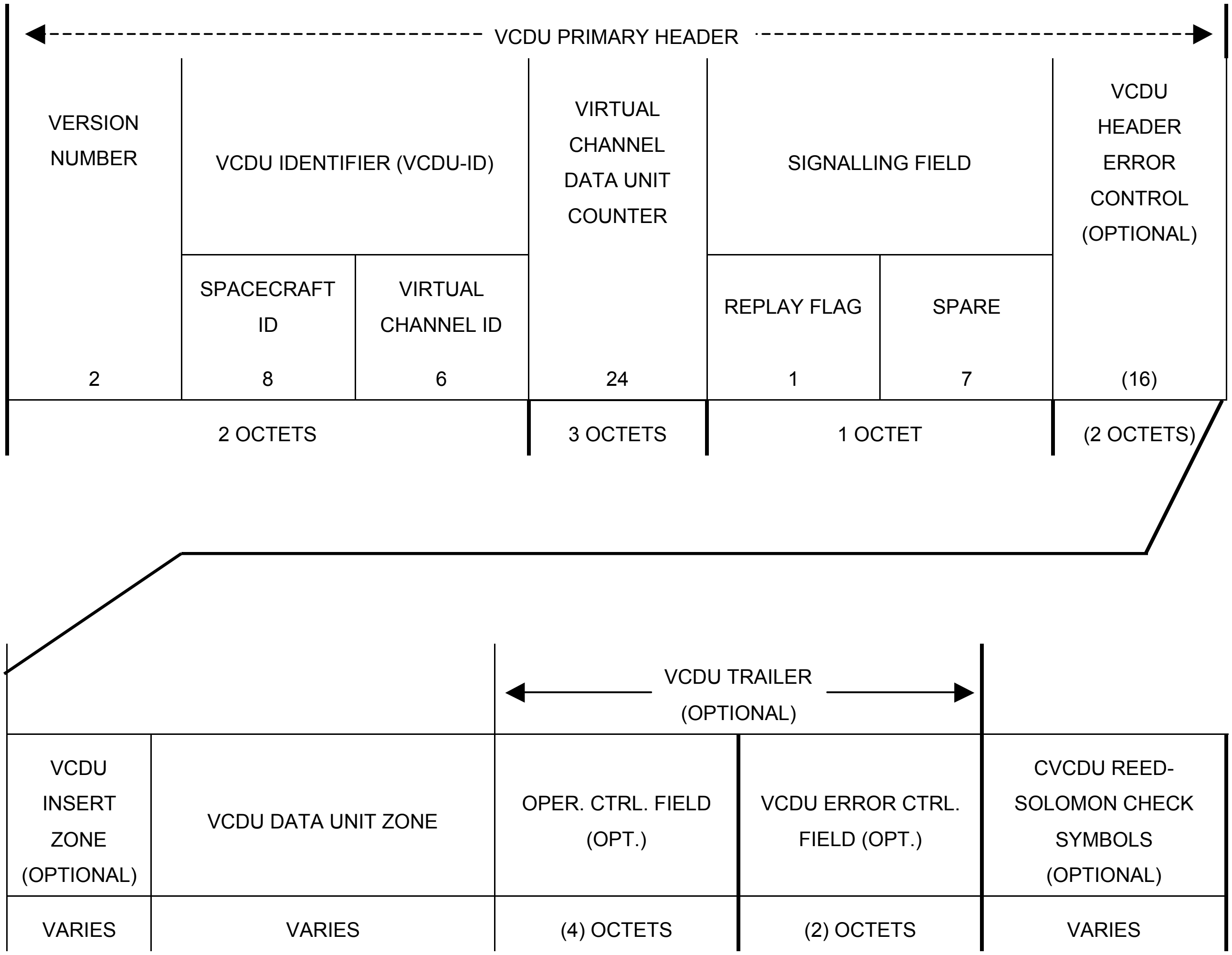


Figure 4-8. Generic Virtual Channel Data Unit Format *(TBR)*

VCDU FORMAT FOR TDRS KU-BAND AND S-BAND AND GN S-BAND

SYNC	PRIMARY HEADER (48 Bits)						VCDU INSERT ZONE (64 Bits)			VCDU DATA UNIT ZONE	FILL DATA	CLCW	REED SOLOMON CHECK SYMBOLS
	VERS No.	SCID	VIRT CH ID	VIRT CH DATA UNIT CNT	R.F.	SPARE	Seconds Field	SPARE	Subseconds Field				
32 Bits	2 Bits	8 Bits	6 Bits	24 Bits	1 Bit	7 Bits	32 Bits	12 Bits	20 Bits	8704 Bits	72 Bits	32 Bits	1280 Bits

VCDU FORMAT FOR S-BAND TDRS MA

SYNC	PRIMARY HEADER (48 Bits)						VCDU INSERT ZONE (64 Bits)			VCDU DATA UNIT ZONE	CLCW	VCDU Frame Error Control Field
	VERS No.	SCID	VIRT CH ID	VIRT CH DATA UNIT CNT	R.F.	SPARE	Seconds Field	SPARE	Subseconds Field			
32 Bits	2 Bits	8 Bits	6 Bits	24 Bits	1 Bit	7 Bits	32 Bits	12 Bits	20 Bits	832 Bits	32 Bits	16 Bits

Figure 4-9. GLAST Mission Specific TDRS VCDU Formats (TBR)

4.3.7 Channel Convolutional Encoding/Viterbi Decoding

4.3.7.1 General

Convolutional encoding and Viterbi decoding with eight levels of quantization shall be used for all S-Band return/down links and Ku-band return links to provide a performance gain relative to an uncoded link. All S-band uplinks/forward links will not utilize convolutional coding.

4.3.7.2 Convolutional Code

a. For the S-Band return/down links and Ku-band return link, a non-systematic (refer to Note 1), transparent (refer to Note 2) convolutional code with a code rate of 1/2 and a constraint length of 7 shall be used.

NOTE

1. Non-systematic original information bits do not appear in the output data stream.

2. Transparent means that if the data sequence I (B) is mapped into the sequence T (B) then the complement of I (B) is mapped into the complement of T (B), where I (B) is the information bit stream and T (B) is the encoded bit stream.

b. The shift register representation of the convolutional encoder is shown in Figure 4-11. The G2 symbol is inverted to provide an increased symbol transition density when the uncoded data signal has a low transition density. The commutation rate and input data rate are coherent.

4.3.7.3 Viterbi Decoding

A phase ambiguity will occur in the carrier reference signal in the receiver whenever a suppressed carrier tracking loop is used to synthesize the coherent carrier reference. The incorrect phase of the reference signal will result in an inversion of the baseband data signal at the demodulator output. In addition, a symbol ambiguity exists because the Viterbi decoder has no prior knowledge whether a given symbol is from the G1 or G2 generator. The Viterbi decoder shall resolve the symbol ambiguity and shall decode the true or inverted symbol. For signals with NRZ-L formatting, either true or inverted data output may be provided at the SN/GN output. For NRZ-M formatting, the true data output is provided at the SN/GN output. NRZ-M is used for all GLAST return/downlinks; therefore, there shall be no phase ambiguity at the SN/GN interface.

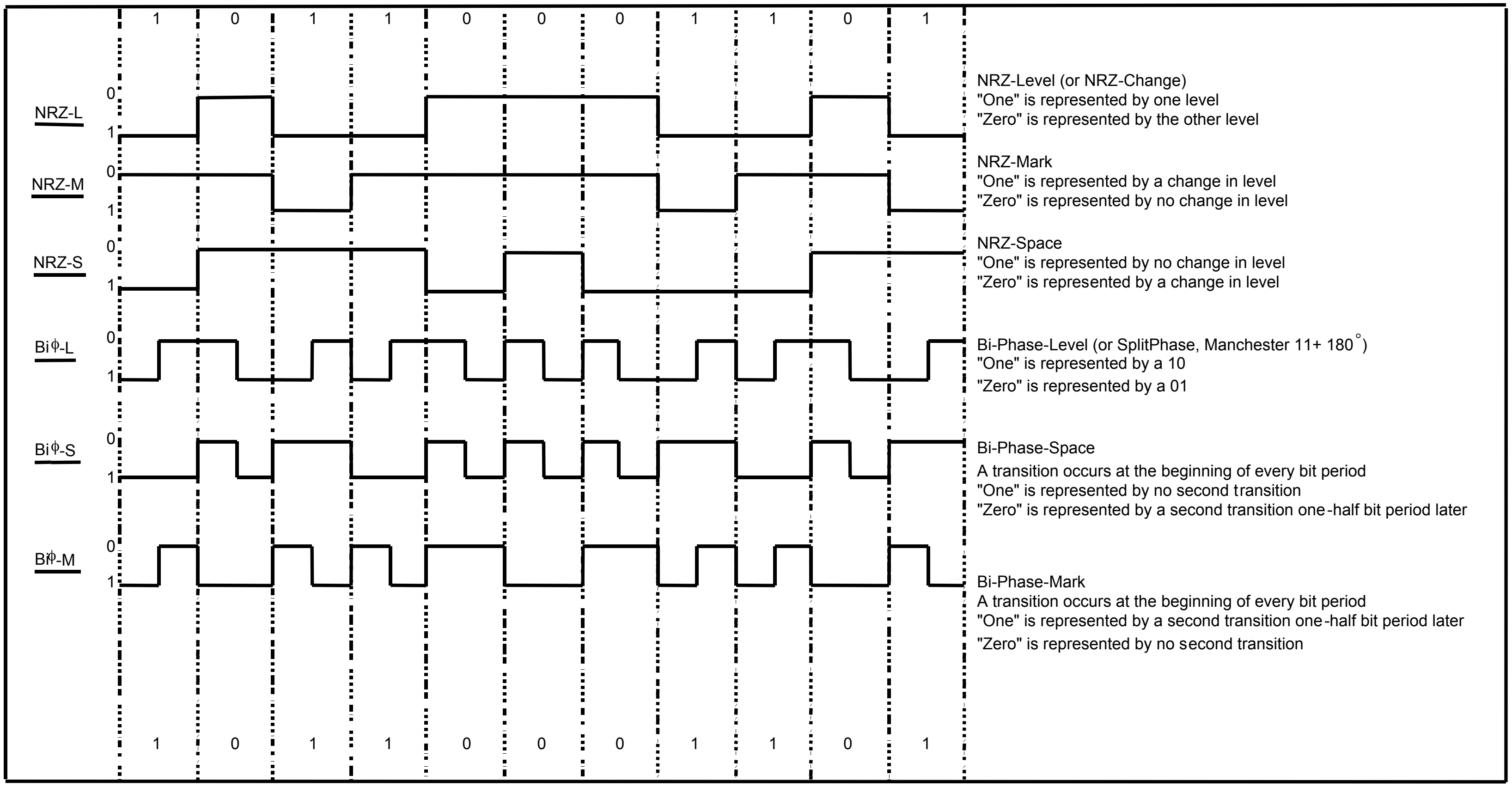


Figure 4-10. Digital Data Signal Formats

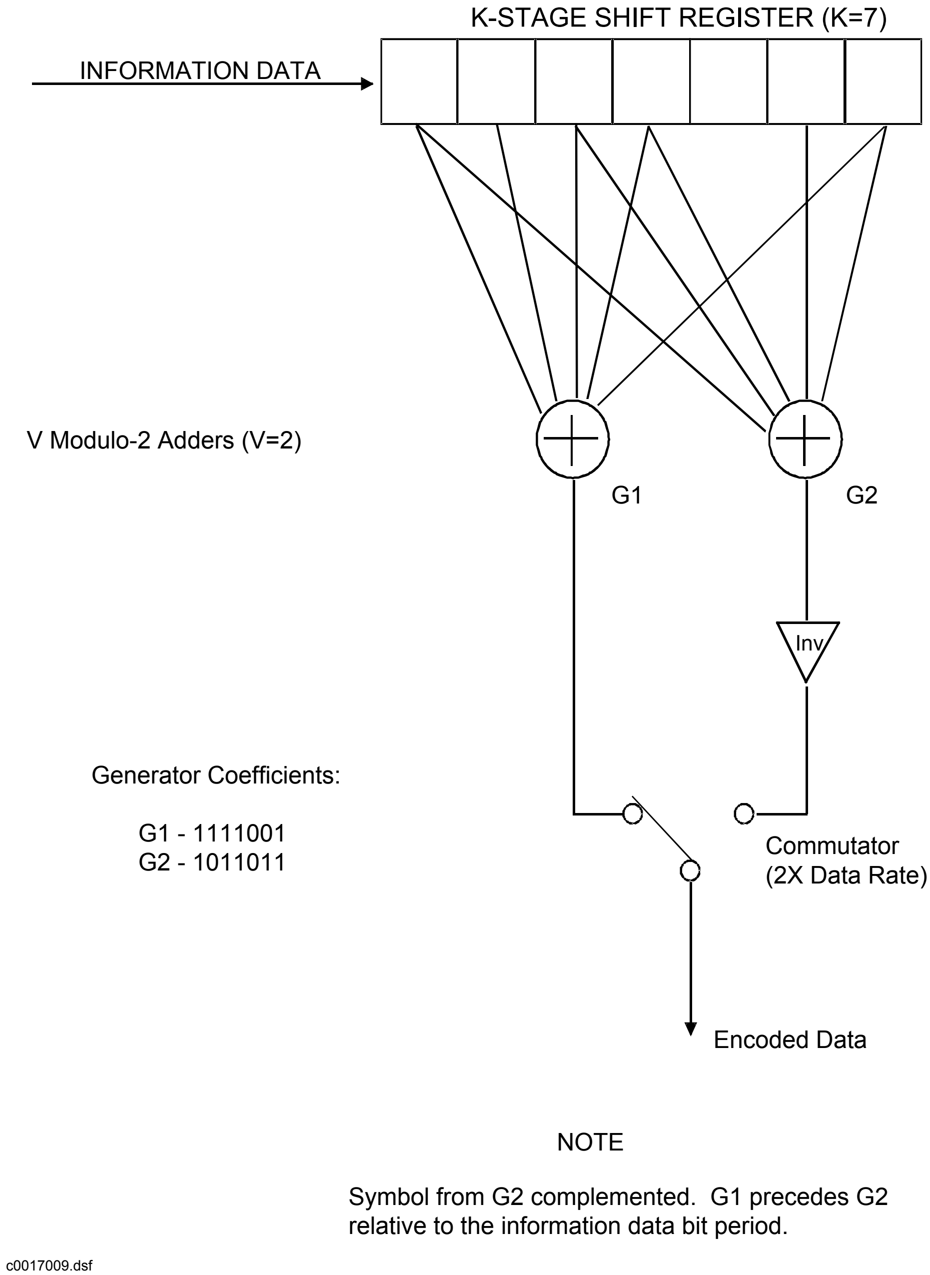


Figure 4-11. Convolutional Encoder Functional Configuration

4.4 RF Characteristics

4.4.1 GLAST Signal Processing

4.4.1.1 General

The following information defines characteristics of the RF signal and signal processing in the GLAST and in SN/GN that are pertinent to the functional performance of the RF links.

4.4.1.2 Carrier Modulation/Demodulation

a. MA and SSA Forward link. For the TDRSS-to-GLAST MA and SSA forward links, Spread Spectrum BPSK (SS-BPSK) is employed for carrier modulation. The functional configuration of the forward link modulation is shown in Figure 4-12.

   1. The command channel signal (PN + command data) phase shift keys a sine wave carrier to form the BPSK modulation.
   2. After despreading in the GLAST, the demodulator will provide coherent BPSK demodulation of the I-channel carrier signal and will deliver the command signal to the bit synchronizer for bit detection.

b. GN Communications Uplinks. For the GN-to-GLAST S-Band uplinks, unspread BPSK is employed for carrier modulation. The unspread signal will demodulate and deliver to the bit synchronizer for bit detection.

c. MA and SSA Return Links. .For the GLAST-to TDRSS MA DAS or Legacy normal mode and SSA contingency mode, DG1 mode 2 is employed, which uses SQPN. The function configuration of DG1 Mode 2 is shown in Figure 4-13. The configuration is as follows:

   1. The data stream is rate _ convolutionally encoded and will be applied directly to both the I and Q channels.
   2. For DG1 Mode 2, the I channel PN code is modulo-2 added asynchronously to the I-channel data. This composite signal phase shift keys a sine wave carrier to become the I-channel carrier of the SQPN modulation. The Q-channel PN code is modulo-2 added asynchronously to the Q-channel data. The Q-channel PN code is delayed by 1/2 chip relative to the I-channel PN code (staggered) for DG1 Mode 2. The composite Q-Channel signal phase shift keys a sine wave carrier to become the Q-channel carrier of the SQPN modulation. The two carrier quadrature phase components are added (such that the power ratio I/Q = 1) to produce a SQPN modulated signal. The I-channel and Q-channel PN codes are both Gold codes which are not synchronized to the forward link PN codes. But, an onboard reference oscillator will be used to clock the return link PN codes at a rate proportional to the GLAST transmit frequency (F_1) by the ratio 31/(240 X 96).
   3. The TDRSS ground terminal utilizes both the I and Q channels from TDRSS. The WSC utilizes a spread-spectrum pseudo-random noise (PN) receiver to acquire, track, despread, and demodulate the I channel and Q

channel portions of the spread spectrum signal. The I and Q channels are combined into a single stream, bit synchronized, and Viterbi decoded. The data will be differentially decoded to NRZ-L to provide at WSC interface.

d. KuSA Return Link. For the GLAST-to-TDRSS KuSA return link, SQPSK modulation will be used with a channel power ratio of 1:1. The WSC receiver will coherently demodulate the SQPSK signal and will deliver the demodulated I & Q channel signals to separate bit synchronizers for bit and clock recovery. Each channel will be Viterbi decoded using 2 branch encoders per channel. Each channel will be differentially decoded to NRZ-L and the two channels will be combined to produce a single data stream. The function configuration of downlink QPSK is shown in Figure 4-14.

e. GN Communications Downlink. For the GLAST-to-GN S-Band downlinks, SQPSK is employed for carrier modulation. The demodulator output shall be processed by a bit synchronizer for bit detection. The two symbol streams will be combined for correct Viterbi decoding. After the Viterbi decoder, the single data stream will be differentially decoded to NRZ-L.

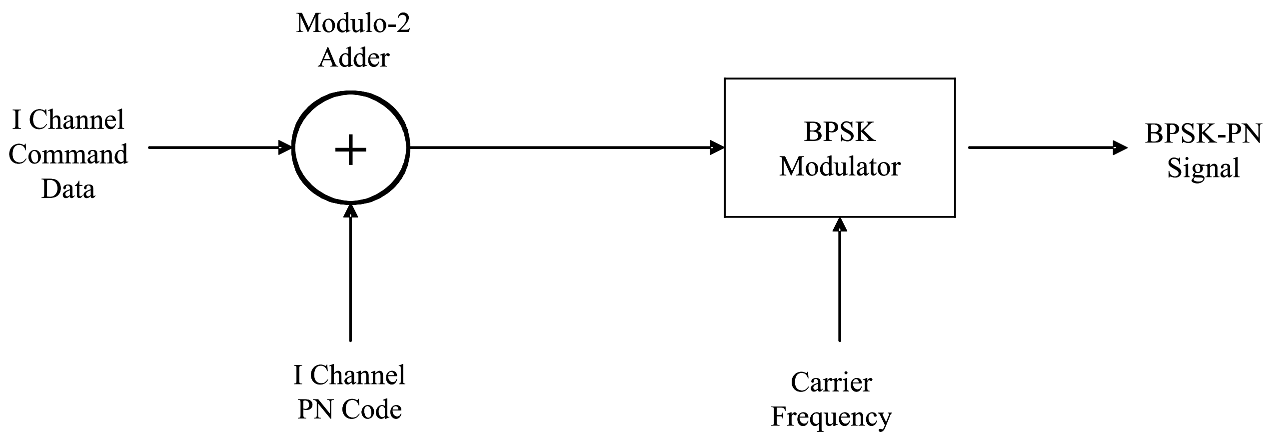


Figure 4-12. S-Band Forward Modulation Functional Configuration

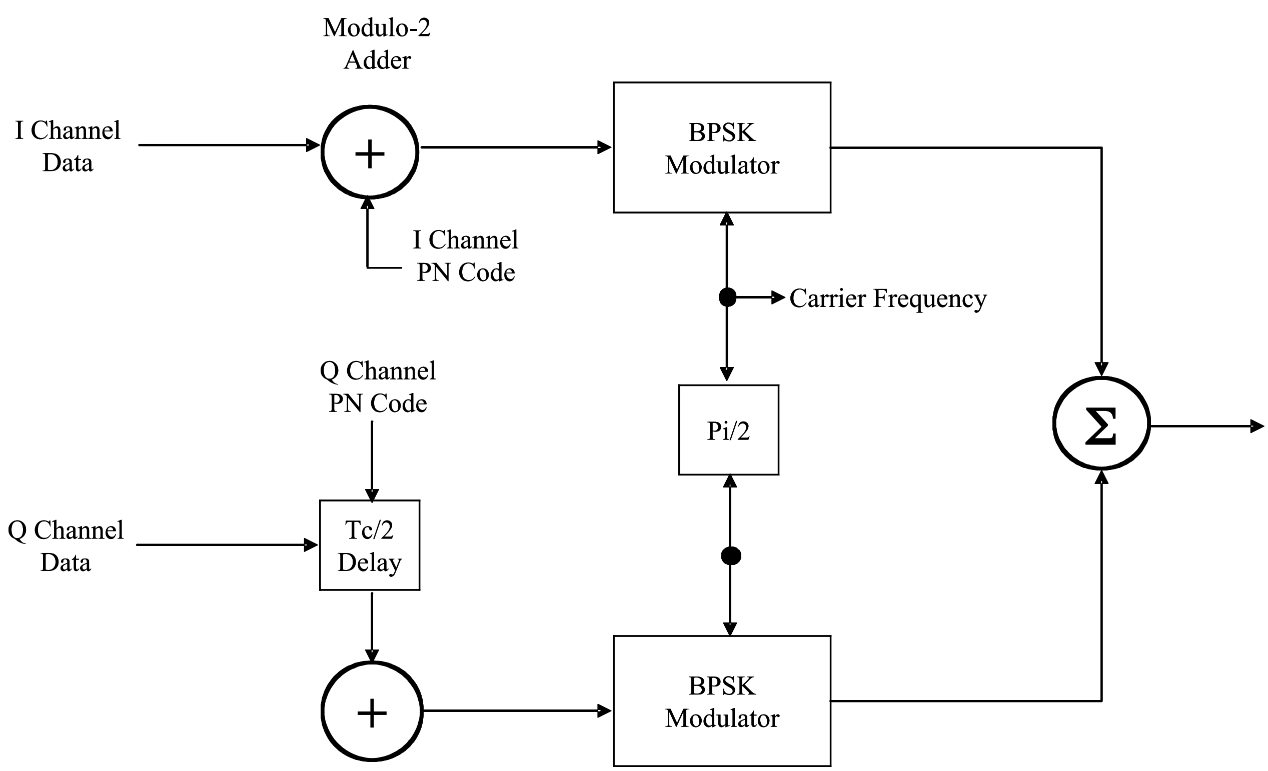


Figure 4-13. MA and SSA DG1 Mode 2 Return Link Modulation Functional Configuration

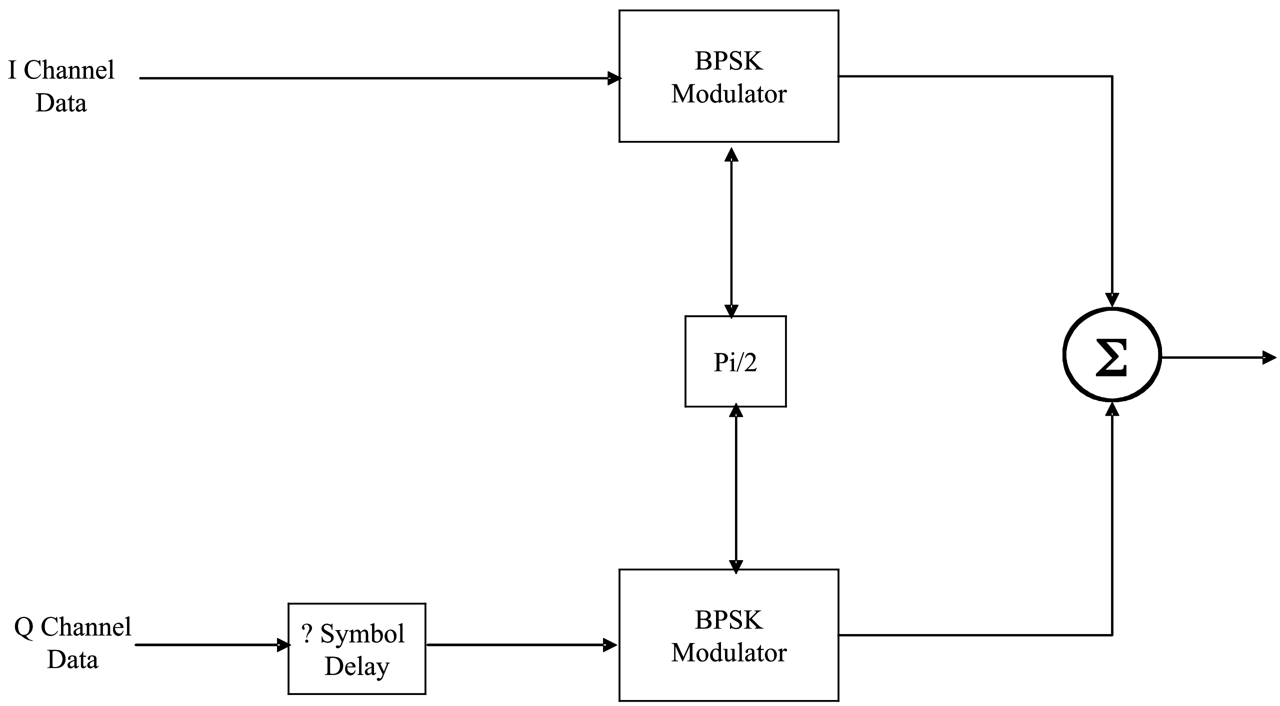


Figure 4-14. KuSA DG2 mode 2 Return/S-band Downlink SQPSK Modulation Functional Configuration

4.4.1.3 Spread Spectrum

a. General. RF spectrum spreading is utilized for the TDRS-to-GLAST S-Band forward link and the GLAST-to-TDRS DG1 Mode 2 S-Band MA and SSA return link. For the forward link, the SN produces the spread RF spectrum by direct sequence BPSK modulation using a 3.08 Mchip/sec chip rate PN sequence. The chip rate is coherent with the forward link carrier frequency. For the DG1 Mode 2 return link, the GLAST produces the spread RF spectrum using a PN rate derived from a local oscillator.

b. Forward Command Channel PN Code. Figure 4-15 shows the functional configuration for the spread spectrum PN code generator for the command channel when NASA code #36 is used. The PN chip rate of ~3 Mchip/sec is coherently related to the transmit carrier frequency by the ratio of 31/21,216. The PN sequence is 1023-bit-length Gold code obtained by modulo-2 addition of two synchronous 1023-bit maximal sequences obtained from two 10-stage feedback shift registers. The GLAST will despread the proper command channel PN code.

c. S-band Return Link. Figure 4-16 is shown the functional configuration for the NASA code #36 DG1 Mode 2 link code generator. The PN sequence is a 2047-bit length Gold code obtained by modulo-2 addition of two synchronous 2047-bit maximal sequences obtained from two 11-stage feedback shift registers as shown.

d. Despreading. In the WSC, a PN receiver will be used to acquire and track the PN sequence.

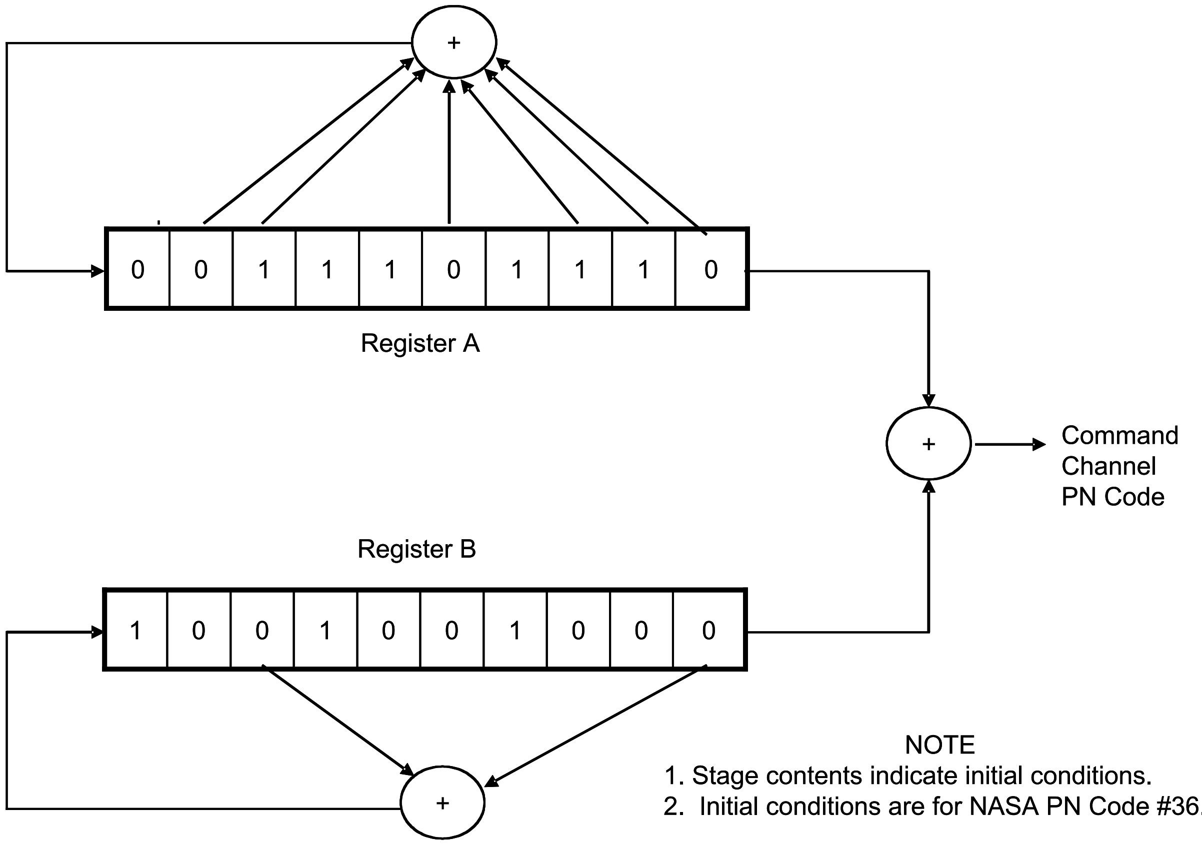


Figure 4-15. Command Channel PN Code Generator Functional Configuration (Code #36)

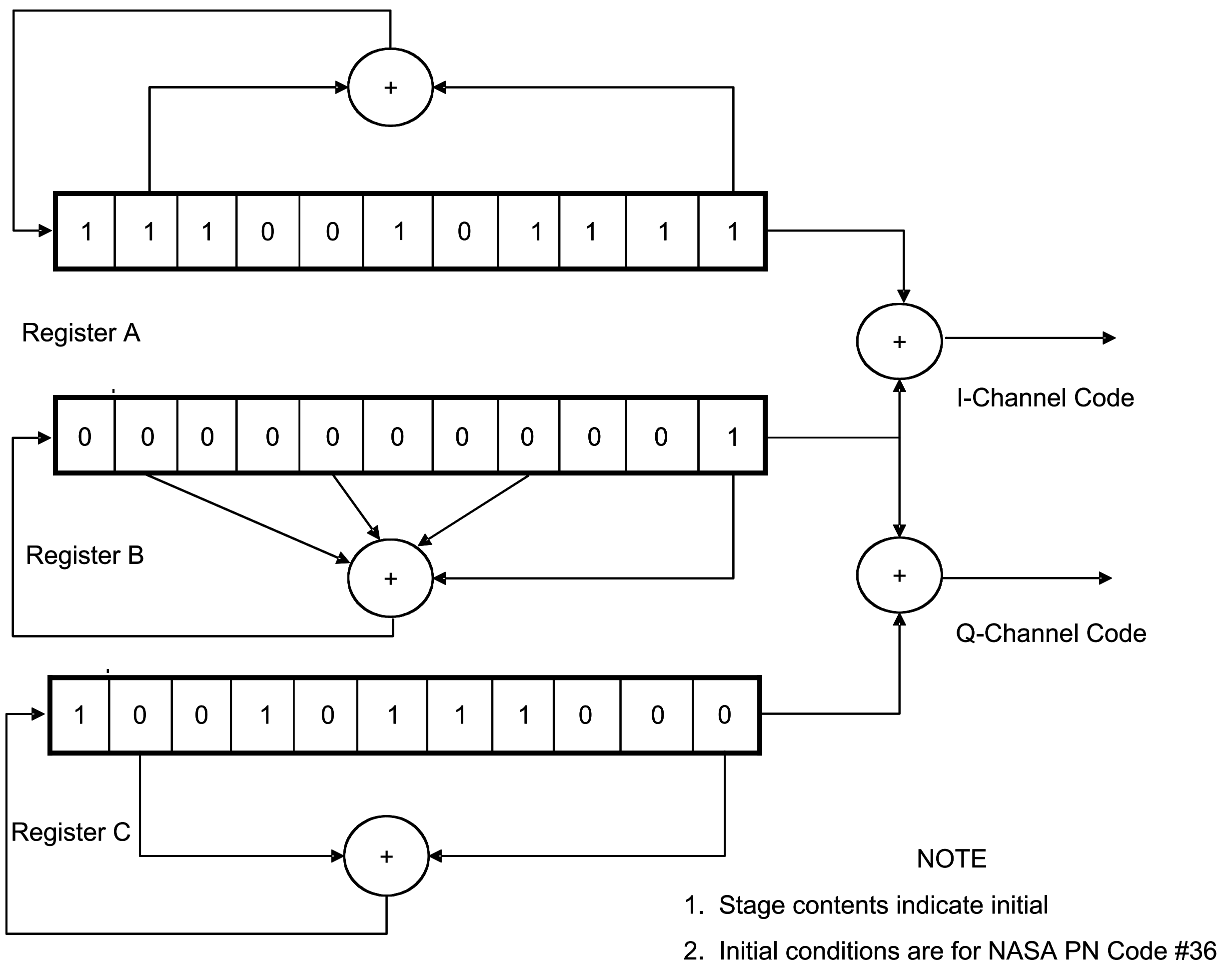


Figure 4-16. DG1 Mode 2 Return PN Code Generator Functional Configuration (Code #36)

4.4.1.4 Signal Acquisition and Tracking

a. S-band Forward Link (TBD). Acquisition of the forward link MA and SSA signals will be accomplished with data modulation. The SNR required to achieve acquisition with a probability of 90 percent or greater is 36.96 dB-Hz (TBR) for MA and 34 dB-Hz (TBR) for SSA. The GLAST can acquire a signal with a maximum frequency offset of $\pm$ 3 kHz. The signal acquisition time is 2 seconds, where the command channel PN code is acquired within 1 second and the suppressed carrier is acquired within 1 second after the command channel PN code acquisition. The SNR required to achieve tracking is 36.96 dB-Hz for MA and 34 dB-Hz for SSA. Once locked to the forward link, the GLAST will be capable of tracking $\pm$ 160 kHz about the assigned center frequency.

b. S-band Uplink (TBD). The GLAST S-Band receiver will detect and phase lock to the uplink signal maintained at a fixed frequency within ±160 kHz of the S-Band system's free running center frequency. The probability of acquisition will be greater than 99 percent in a period corresponding to one sweep period when the C/No is between 75 and 120 dB-Hz.

c. S-band and Ku-band Return Link.

   1. Acquisition Performance. The total TDRSS MA, SSA, or KuSA return service signal acquisition time is the sum of the following:

      (a) PN Code (if applicable) and carrier acquisition time: within 1 second, with 90 percent probability.

      (b) Decoder/symbol synchronization time: within 6500/(channel data rate in bps), with 99 percent probability.

      (c) Autotrack acquisition time (when the TDRSS KuSA return service autotrack mode is enabled): within 10 seconds, with 99 percent probability

   TDRSS will acquire the GLAST provided:

      (a) The received power (Prec) at TDRS is at least –193.5 dBW (MA), -202.0 dBW (SSA), -183.3 dBW (KuSA Autotrack),-180.8 dBW (KuSA LEO Program Track), or consistent with the Prec required for 10^{-5} BER for the relevant MA, SSA, and KuSA return links.

      (b) The acceleration and jerk of the GLAST does not exceed 15 m/sec^2 and 0.02 m/sec^3, respectively.

      (c) The GLAST state vector provided to the SN has an orbit-epoch error within $\pm$ 9 seconds.

      (d) The S-band GLAST transmit frequency during the noncoherent mode of operation is accurate to $\pm$ 700 Hz (S-band).

      NOTE: After the start of the return service, a request can be made that the SN perform an expanded frequency search. The SN can acquire PN code (if applicable) and carrier for a non-coherent return link within 3 seconds for a GLAST ground control-defined spacecraft transmit frequency uncertainty of $\pm$3 kHz (S-band, DG1 and SQPSK DG2).

(e) The Ku-band GLAST transmit frequency during the noncoherent mode of operation is accurate to $\pm$5 kHz (Ku-band).

NOTE: After the start of the return service, a request can be made that the SN perform an expanded frequency search. The SN can acquire PN code (if applicable) and carrier for a non-coherent return link within 3 seconds for a GLAST ground control-defined spacecraft transmit frequency uncertainty of $\pm$20 kHz (DG1 mode 2 and DG2 noncoherent).

(f) The GLAST return link has greater than or equal to 64 data bit transitions within any sequence of 512 data bits and the maximum number of consecutive data bits without a transition must be less than or equal to 64.

2. Tracking Performance. TDRSS will track the return link continuously provided that all the constraints defined 4.4.1.4.c above are met.

d. S-Band Downlink (TBD). The carrier loop in the GN ground station receiver will automatically acquire and track SQPSK modulated signals received within 100 kHz of the nominal carrier frequency, provided that the received C/No in the carrier tracking loop (60 Hz) is at least 15 dB.

4.4.1.5 Doppler Tracking/Compensation

a. No Doppler tracking of the platform is required.(TBR)

b. Doppler compensation will be provided, upon request, of the forward link transmitted carrier frequency and PN chip rate (if applicable). The Doppler shifted carrier frequency arriving at the GLAST, Fr, will be the nominal center frequency (f_o) of the GLAST receiver $\pm$ E Hz. E = (70 x $\ddot{R}$) + C; $\ddot{R} \leq 15$ m/sec^2 and C = 10 Hz.

NOTE: The nominal center frequency of receiver should be accurate to within $\pm$700 Hz (S-Band). After the start of the forward service, a request can be made that the SN perform a forward frequency sweep. For S-Band forward service, the SN will initiate the forward frequency sweep at f_o-3 kHz and linearly swept to f_o+3 kHz in 120 seconds and held at f_o+3 kHz thereafter. The forward frequency sweep does not impact simultaneous SN Doppler compensation of the forward service carrier and PN chip rate (if applicable).

4.4.2 TDRSS RF Signal Characteristics

4.4.2.1 TDRSS Forward Link RF Signal Characteristics

TDRS provides the forward link RF signal characteristics within the values shown in Table 4-6 for all forward link services.

4.4.2.2 TDRSS Return Link RF Signal Characteristics

The GLAST S-Band return link RF signal parameters for the telemetry channel are listed in Table 4-7.

4.4.2.3 Frequency Stability

a. TDRSS Frequency Stability. The carrier generated by the TDRSS WSC and relayed through a TDRS is sufficiently stable to permit airborne demodulation and carrier extraction. The carrier frequency transmitted by the TDRSS ground station and relayed through the TDRS shall have a stability of 5 parts in 10^{12} short term (1 second averaging time) and 2 parts in 10^{12} long term, excluding atmospheric effects.

b. GLAST Frequency Stability (TBD). The GLAST will use an internal reference oscillator for both the receiver and the transmitter. The GLAST oscillator frequency stability at any constant temperature (±0.5 degrees C) in the mission temperature range will meet the values listed in Table 4-7. At a minimum, a temperature range of –10 degrees C to +55 degrees C should be considered. The nominal center frequency of the oscillator should be specified to within ± 700 Hz for S-Band and ±5 kHz for Ku-band; however, the SN is capable of performing expanded frequency sweeps on the forward link (see paragraph 4.4.1.5.b) and expanded frequency search on the return link (see paragraph 4.4.1.4.c).

4.5 Interface Characteristics Summary

Table 4-8 through Table 4-12 summarize the data channel and RF transmission parameters for each RF link. The following stipulations apply to these tables:

a. Bit rates and carrier frequencies are specified at the link transmitter and will differ at the receiver by the appropriate Doppler shifts.

b. The minimum transmitted EIRP is the required minimum signal EIRP toward the receiver and includes the transmitter RF signal power, transmitting circuit losses, transmitting antenna gain towards the receiver. The TDRS EIRP also includes the TDRS transponder loss.

c. The required effective power received at the TDRS, referenced at the input to the antenna, is for a BER of 10^{-5} at the required data rate and signal parameters.

d. The required carrier power received at the Ground Station, referenced after the antenna, is for a BER of 10^{-5} at the required data rate and signal parameters.

NOTE

This configuration implies total GLAST compliance (0 dB constraint loss), a non-RFI environment (0 dB RFI degradation), and perfect antenna polarization coupling (0 dB polarization loss).

Table 4-6. Forward Link Baseband and RF Signal Characteristics

Parameter	MA	SSA
Modulator phase imbalance (peak)	±3 degrees	±3 degrees
Modulator gain imbalance	±0.25 dB	±0.25 dB
Symbol asymmetry (peak)	±3 percent	±3 percent
Symbol rise time (90% of initial state to 90% of final state)	≤5 percent of symbol duration	≤5 percent of symbol duration
Phase nonlinearity (peak)	±0.12 radian over ± 2.1 MHz	±0.15 radian over ±7 MHz
Gain flatness (peak)	±1.2 dB over ±2.1 MHz	±0.8 dB over ±7 MHz
Gain slope (peak)	±0.1 dB/MHz	±0.1 dB/MHz
AM/PM	≤13 degrees/dB	≤10 degrees/dB
Data bit jitter (peak)	≤1 percent	≤1 percent
Spurious PM (rms)	≤1 degree	≤1 degree
Spurious outputs (note)	≥27 dBc	≥27 dBc
Incidental AM (peak)	≤2 percent	≤2 percent
Phase Noise 1 Hz - 10 Hz 10 Hz - 32 Hz 32 Hz - 1 kHz 1 kHz - 3 MHz 1 kHz - 6 MHz	 ≤1.5 degrees rms ≤1.5 degrees rms ≤4.0 degrees rms ≤2.0 degrees rms -----	 ≤1.5 degrees rms ≤1.5 degrees rms ≤4.0 degrees rms ----- ≤2.0 degrees rms

Table 4-7. Return Link Baseband & RF Signal Parameter Requirements (User Constraints)

Parameter	Requirement		
	MA	SSA	KuSA
Minimum channel symbol transition density	≥128 randomly distributed symbol transitions within any sequence of 512 symbols	≥128 randomly distributed symbol transitions within any sequence of 512 symbols	≥128 randomly distributed symbol transitions within any sequence of 512 symbols
Consecutive channel symbols without a symbol transition	≤64 symbols	≤64 symbols	≤64 symbols
Symbol asymmetry (peak)	≤3 percent	≤3 percent	≤3 percent
Symbol rise time (90 percent of initial state to 90 percent of final state)	≤5 percent of symbol time	≤5 percent of symbol time	≤5 percent of symbol time
Symbol jitter & jitter rate	≤0.1 percent	≤0.1 percent	≤0.1 percent
Phase imbalance DG1 Mode 1 and 2 DG2	 ≤ ± 5 degrees	 ≤ ± 5 degrees	 ≤ ± 3 degrees
Gain imbalance DG1 Mode 1 and 2 DG2:	 ≤ ± 0.5 dB	 ≤ ± 0.5 dB	 ≤ ± 0.25 dB
Phase nonlinearity (applies for all types of phase nonlinearities) (peak) DG1 Mode 1 and 2 DG2:	≤4.0 degrees over ±2.1 MHz	≤4.0 degrees over ±2.1 MHz	≤3.0 degrees over ±80 MHz
Gain flatness (peak) DG1 Mode 1 and 2 DG2:	 ≤0.4 dB over ±2.1 MHz	 ≤0.4 dB over ±2.1 MHz	 ≤0.3 dB over ±80 MHz
Gain slope (peak)	Not specified	Not specified	≤0.1 dB/MHz over ±80 MHz
AM/PM DG1 Mode 1 and 2 DG2	 ≤15 degrees/dB	 ≤15 degrees/dB	 ≤12 degrees/dB

Table 4-7. Return Link Baseband & RF Signal Parameter Requirements (User Constraints) (Cont'd)

Parameter	Requirement		
	MA	SSA	KuSA
Frequency stability (peak) 1-second average time 5-hour observation time 48-hour observation time	For ± 700 Hz ≤3 x 10E-9 ≤1 x 10E-7 ≤3 x 10E-7	For ± 700 Hz ≤3 x 10E-9 ≤1 x 10E-7 ≤3 x 10E-7	For ± 5 kHz ≤3 x 10E-9 ≤1 x 10E-7 ≤3 x 10E-7
Incidental AM (peak) For autotrack performance: At frequency: 10 Hz – 10 kHz At frequency: 10 Hz – 2 kHz	≤5 percent	≤5 percent	≤5 percent ≤3percent ≤0.6 percent
Untracked spurious PM DG1 DG2	 ≤2 degrees rms	 ≤2 degrees rms	 ≤2 degrees rms
Phase noise (noncoherent) DG1 Mode 2: 1 Hz – 10 Hz 10 Hz – 100 Hz 100 Hz – 1 kHz 1 kHz – 3 MHz 1 kHz – 6 MHz DG2 Mode 2: 1 Hz – 10 Hz 10 Hz – 100 Hz 100 Hz – 1 kHz 1 kHz – 6 MHz	(Doppler tracking NOT required) Baud rate < 4.5 ksps ≤3.8 degrees rms ≤1.8 degrees rms ≤1.4 degrees rms ≤1.4degrees rms	(Doppler tracking NOT required) Baud rates<40 ksps ≤7.5 degrees rms ≤2.0 degrees rms ≤1.5 degrees rms --------- ≤1.5 degrees rms	(Doppler tracking NOT required) Baud rates> 6 Msps ≤50.0 degrees rms ≤10.0 degrees rms ≤2.0 degrees rms ≤2.0 degrees rms
In-band spurious outputs DG1 DG2	 ≥23 dBc	 ≥23 dBc	 ≥30dBc
I/Q symbol skew (peak)	≤3 percent	≤3 percent	≤3 percent

Table 4-7. Return Link Baseband & RF Signal Parameter Requirements (User Constraints) (Cont'd)

Parameter	Requirement		
	MA	SSA	KuSA
I/Q PN skew (relative to 0.5 chip)	≤0.01 chip	≤0.01 chip	N/A
PN chip rate, DG1 Mode 2 (relative to absolute coherence with carrier rate)	≤0.01 Hz peak at PN rate	≤0.01 Hz peak at PN rate	N/A
PN power suppression	≤0.3 dB	≤0.3 dB	N/A
Permissible Prec variation (without user reconfiguration message)	≤12 dB	≤12 dB	≤12 dB
Permissible rate of Prec variation	≤10 dB/sec	≤10 dB/sec	≤10 dB/sec
Maximum Prec	-161.2 dBW	-149.7 dBW	-149.2 dBW
KuSA axial ratio for autotrack	N/A	N/A	≤3 dB

Table 4-8. TDRSS -to-GLAST Forward Link Interface Characteristics

Information		Channel Encoding/ Decoding	Spectrum Spreading	Carrier		Minimum TDRSS EIRP	Antenna Polarization
Service	**Rate (Note 1)**			**Modulation**	**Frequency (Note 2)**		
MAF	250 bps	NRZ-M	PN Code Chip Rate = 3.078 Mc/sec L = 1023 bits (short code)	SS-BPSK	2106.4 MHz	34 dBW	LHCP (Omni)
SSAF	4000 bps	NRZ-M	PN Code Chip Rate = 3.078 Mc/sec L = 1023 bits (short code)	SS-BPSK	2106.4 MHz	48.5 dBW (High Power Mode)	LHCP (Omni)

NOTES:

1. The rate given in this column is the information rate prior to any coding. Any coding and data formatting is transparent to WSC and must be performed prior to receipt at the SN.
2. The center frequency does not include the GLAST Doppler shift.

Table 4-9. GN-to-GLAST Uplink Interface Characteristics

Information		Channel Encoding/ Decoding	Carrier		Subcarrier Frequency	Modulation Index	Antenna Polarization	Minimum EIRP
Ground Stations	**Rate (Note 1)**		**Modulation**	**Frequency (Note 2)**				
11.3-m Wallops Island	2.0 kbps	NRZ-M	BPSK/PM	2106.4 MHz	16 kHz	1.0 rad.	LHCP (Omni)	96 dBm
9-m MILA(TBD)								93 dBm
13-m USN, Hawaii								98 dBm
13-m USN, Australia								98 dBm

NOTES:

1. The rate given in this column is the information rate prior to any coding. Any coding and data formatting is transparent to GN and must be performed prior to receipt at the GN.
2. The center frequency does not include the GLAST Doppler shift.

Table 4-10. GLAST-to-TDRSS Return Link Interface Characteristics

Information		Channel Coding	Carrier		Antenna Polarization	Required Effective Power (dBW) (note 1)	Other Losses (note 2)
Channel	Rate (note 3)		Modulation	Frequency			
MAR DG1 Mode 2	I = 1 kbps Q = 1 kbps (identical data)	NRZ-M RS (223,255) and Rate 1/2	SQPN I/Q=1:1 PN Code Chip Rate: 3.078 Mc/sec L = (2^{11}-1)	2287.5 MHz (Non-coherent)	LHCP (Omni)	-191.94 dBW	1.17 dB
SSAR DG1 Mode 2	I = 1, 2,4,& 8 kbps Q = 1, 2,4 & 8 kbps (identical data)	NRZ-M RS (223,255) and Rate 1/2	SQPN I/Q=1:1 PN Code Chip Rate: 3.078 Mc/sec L = (2^{11}-1)	2287.5 MHz (Non-coherent)	LHCP (Omni)	-201.76 dBW (1 kbps) -198.75 dBW (2 kbps) -195.74 dBW (4 kbps) -192.73 dBW (8 kbps)	1.37 dB
KuSAR DG2 non-coherent	I = 20 Mbps Q = 20 Mbps Alternate I/Q bits	NRZ-M RS (223,255) and Rate 1/2	SQPSK I/Q=1:1	15003.4 MHz (Non-coherent)	RHCP (HGA)	-170.78 dBW (autotrack) -168.38 dBW (LEO program track)	0.45 dB

Notes:

1. Required effective power (zero constraint loss, zero RFI loss, zero polarization loss) required for 10^{-5} BER at the GLAST data rate and signal parameters. The MAR service may be subject to outages due to self/mutual interference a 2 dB allocation for this was included in the Prec determination. If the required effective power is not met, the SN support is performed on a best-effort basis.
2. Other losses including user constraint loss, RFI loss, polarization loss, and GLAST pointing loss.
3. Prior to applying the convolutional and differential encoding, GLAST will Reed-Solomon encode both the SSA and KuSA data streams. The data rates listed in this table are the rates prior to convolutional encoding.

Table 4-12. GLAST-to-GN S-Band Downlink Interface Characteristics

Ground Stations	Data Rate	Channel Coding	Carrier Modulation	Frequency	Antenna (Polarization)	Minimum Required Power at Ground Station with a Unity Gain Antenna (note 1)
11.3-m Wallops Island 9-m MILA(TBD) 13-m USN, Hawaii 13-m USN, Australia	I = 1.25 Mbps Q= 1.25 Mbps Alternate I/Q	NRZ-M RS (223,255) and Rate 1/2	OQPSK I/Q=1:1	2287.5 MHz (nominal)	LHCP (Omni)	-178.72 dBW (11.3-m) -179.72 dBW (9-m) -180.72 dBW (13-m)

NOTES:

1. Equivalent received carrier power for data at a BER of 10^{-5}. This minimum value applies for an available signal margin of 0 dB, which does not include any required performance margin. If applicable, combiner loss is included in determining the minimum required power. If the minimum required carrier power is not met, the GN support is performed on a best-effort basis.

Appendix A. RF Link Calculations

Link 1. GLAST MA Forward Link with 250 bps Data Rate

```
             *** FORWARD LINK CALCULATION -- NETWORK SYSTEMS ENGINEER ANALYSIS ***
    GSFC C.L.A.S.S. ANALYSIS #1        DATE & TIME: 09/24/03  6:40:45   PERFORMED BY: NANCY HUYNH
       USERID:  GLAST                  LINKID:  MA FWD                  RELAY SAT.:  TDRS-East

             TYPE OF TRACKING: PROGRAM TRACK                        FIELD OF VIEW:  LEO FOV

SERVICE:   FREQUENCY:    DATA RATE:    POLAR:   RANGE CASE:    ALTITUDE:     ELEVATION:    RANGE:
  MA       2106.4 MHz    0.25 Kbps      LCP       MAXIMUM       565.0 Km       1.5 Deg   44244.2 Km


     --COHERENT LINK
```

PARAMETER	VALUE	TOLERANCE	REMARKS
1. RELAY NETWORK EIRP-DBW	34.00	-	STDN 101.2
2. FREE SPACE LOSS-DB	191.83	-	NOTE B
3. POLARIZATION LOSS-DB	0.67	0.01	NOTE A
4. USER ANTENNA GAIN-DB	-2.70	0.00	NOTE A
5. USER ANTENNA POINTING LOSS-DB	0.00	0.10	NOTE A
6. USER PASSIVE LOSS-DB	2.92	0.10	NOTE A
7. USER RECEIVED POWER-DB	-164.12	-	SUM 1 THRU 6
8. ATMOSPHERIC LOSS-DB	*	*	NOTE B
9. RAIN ATTENUATION-DB	0.00	-	NOTE A
10. RFI LOSS-DB	*	-	NOTE B
11. DYNAMICS LOSS-DB	*	*	NOTE B
12. USER EFFECTIVE RECEIVED POWER-DBW	-164.12	-	SUM 7 THRU 11
13. USER NOISE SENSITIVITY-DBW/HZ	-201.40	0.30	NOTE A
14. USER RECEIVED-P/N0-DB-HZ	37.28	-	12 MINUS 13
15. USER REQUIRED ACQUISITION-P/N0-DB-HZ	36.96	3.00	NOTE A
16. USER ACQUISITION MARGIN-DB	0.32	-	14 MINUS 15
		-3.51	SUM (NOTE C)
		-3.02	RSS
17. COMMAND/TOTAL POWER RATIO-DB	0.00	-	NOTE A
18. USER TRANSPONDER LOSS-DB	2.40	1.00	NOTE A
19. RECEIVED COMMAND-P/N0-DB	34.88	-	SUM 14,17,18
20. COMMAND DATA RATE-DB-HZ	23.98	-	NOTE A
21. USER RECEIVED EB/N0-DB	10.90	-	19 MINUS 20
22. USER REQUIRED EB/N0-DB	9.60	1.00	NOTE A
23. EFFECTIVE USER COMMAND MARGIN-DB	1.30	-	21 MINUS 22
		-2.51	SUM (NOTE C)
		-1.45	RSS

```
 NOTE A:  PARAMETER VALUE FROM USER PROJECT - SUBJECT TO CHANGE
 NOTE B:  FROM CLASS ANALYSIS IF COMPUTED
 NOTE C:  SUM=-ABS(SUM(ABS. VALUES OF TOLERANCES))
  * = NOT CONSIDERED IN THE ANALYSIS
```

Link 2. GLAST SSA Forward Link with 4 kbps Data Rate

```
             *** FORWARD LINK CALCULATION -- NETWORK SYSTEMS ENGINEER ANALYSIS ***
    GSFC C.L.A.S.S. ANALYSIS #1         DATE & TIME: 09/24/03  6:50:43   PERFORMED BY: NANCY HUYNH
       USERID:  GLAST                    LINKID:  SSA FWD                 RELAY SAT.:  TDRS-East

             TYPE OF TRACKING: PROGRAM TRACK                        FIELD OF VIEW:  PEFOV

SERVICE:   FREQUENCY:    DATA RATE:    POLAR:   RANGE CASE:    ALTITUDE:     ELEVATION:    RANGE:
  SSA      2106.4 MHz     4.00 Kbps     RCP       MAXIMUM       565.0 Km       1.5 Deg   44244.2 Km


    --COHERENT LINK
----------------------------------------------------------------------------------------------------
 PARAMETER                                                 VALUE          TOLERANCE  REMARKS
----------------------------------------------------------------------------------------------------
  1. RELAY NETWORK EIRP-DBW                                48.50                 -      STDN 101.2
  2. FREE SPACE LOSS-DB                                   191.83                 -      NOTE B
  3. POLARIZATION LOSS-DB                                   0.67              0.01      NOTE A
  4. USER ANTENNA GAIN-DB                                  -2.70              0.20      NOTE A
  5. USER ANTENNA POINTING LOSS-DB                          0.00              0.10      NOTE A
  6. USER PASSIVE LOSS-DB                                   2.92              0.10      NOTE A
  7. USER RECEIVED POWER-DB                              -149.62                 -      SUM 1 THRU 6

  8. ATMOSPHERIC LOSS-DB                                    *                    *      NOTE B
  9. RAIN ATTENUATION-DB                                    0.00                 -      NOTE A
 10. RFI LOSS-DB                                            *                    -      NOTE B
 11. DYNAMICS LOSS-DB                                       *                    *      NOTE B
 12. USER EFFECTIVE RECEIVED POWER-DBW                   -149.62                 -      SUM 7 THRU 11

 13. USER NOISE SENSITIVITY-DBW/HZ                       -201.40              0.30      NOTE A
 14. USER RECEIVED-P/N0-DB-HZ                              51.78                 -      12 MINUS 13
----------------------------------------------------------------------------------------------------
 15. USER REQUIRED ACQUISITION-P/N0-DB-HZ                  34.00              3.00      NOTE A
 16. USER ACQUISITION MARGIN-DB                            17.78                 -      14 MINUS 15
                                                                       -3.71  SUM (NOTE C)
                                                                       -3.02  RSS
----------------------------------------------------------------------------------------------------
 17. COMMAND/TOTAL POWER RATIO-DB                           0.00                 -      NOTE A
 18. USER TRANSPONDER LOSS-DB                               2.40              1.00      NOTE A
 19. RECEIVED COMMAND-P/N0-DB                              49.38                 -      SUM 14,17,18

 20. COMMAND DATA RATE-DB-HZ                               36.02                 -      NOTE A
 21. USER RECEIVED EB/N0-DB                                13.36                 -      19 MINUS 20
 22. USER REQUIRED EB/N0-DB                                 9.60              1.00      NOTE A
 23. EFFECTIVE USER COMMAND MARGIN-DB                       3.76                 -      21 MINUS 22
                                                                       -2.71  SUM (NOTE C)
                                                                       -1.47  RSS
----------------------------------------------------------------------------------------------------


 NOTE A:  PARAMETER VALUE FROM USER PROJECT - SUBJECT TO CHANGE
 NOTE B:  FROM CLASS ANALYSIS IF COMPUTED
 NOTE C:  SUM=-ABS(SUM(ABS. VALUES OF TOLERANCES))
  * = NOT CONSIDERED IN THE ANALYSIS
```

Link 3. GLAST MA Return Link with 1 kbps Data Rate

*** RETURN LINK CALCULATION -- NETWORK SYSTEMS ENGINEER ANALYSIS ***

GSFC C.L.A.S.S. ANALYSIS #1 DATE & TIME: 03/10/04 11: 2: 1 PERFORMED BY: NANCY HUYNH

USERID: GLAST LINKID: MA RTN RELAY SYS.: TDRS-East TO STGT

TYPE OF TRACKING: PROGRAM TRACK FIELD OF VIEW: LEO FOV

SERVICE:	FREQUENCY:	DATA GROUP/MODE:	POLAR:	RANGE CASE:	ALTITUDE:	ELEVATION:	RANGE:
MA	2287.5 MHz	DG-1 MODE-2A	LCP	MAXIMUM	565.0 Km	1.5 Deg	44244.2 Km

I CHANNEL	Q CHANNEL
DATA RATE = 1.000 KBPS	DATA RATE = 1.000 KBPS
MOD 2 ADDED TO PN	MOD 2 ADDED TO PN
SYMBL FMT = NRZ-M	SYMBL FMT = NRZ-M
RATE 1/2 CODED	RATE 1/2 CODED
COMBINED	COMBINED

SPACE-SPACE LINK		NOTES
1 USER TRANSMIT POWER, dBW	7.56	User Provided Data
2 PASSIVE LOSS, dB	3.72	User Provided Data
3 USER ANTENNA GAIN, dBi	-1.70	User Provided Data
4 POINTING LOSS, dB	0.00	User Provided Data
5 USER EIRP, dBW	2.14	(1)-(2)+(3)-(4)
6 SPACE LOSS, dB	192.55	CLASS Analysis
7 ATMOSPHERIC LOSS, dB	0.00	Not Considered
8 MULTIPATH LOSS, dB	0.00	Not Considered
9 POLARIZATION LOSS, dB	0.67	User Provided Data
10 SSL RAIN ATTENUATION, dB	0.00	User Provided Data
11 Prec AT INPUT TO TDRS, dBW	-191.08	(5)-(6)-(7)-(8)-(9)-(10)
12 TDRS SINGLE ELEMENT G/T, dB/K	-11.17	CLASS Database
13 SELF/MUTUAL INTERFERENCE LOSS, dB	2.00	CLASS Database
14 C/N0 AT TDRS, dB-Hz	24.35	(11)+(12)-(13)-K
15 BANDWIDTH, dB-Hz	68.54	CLASS Database
16 C/N AT TDRS, dB	-44.18	(14)-(15)

SPACE-GROUND LINK		
17 TDRS EIRP, dBW	26.33	CLASS Database
18 PATH LOSS, dB	207.32	CLASS Analysis
19 ATMOSPHERIC LOSS, dB	0.19	CLASS Analysis
20 POLARIZATION LOSS, dB	0.03	CLASS Database
21 RAIN ATTENUATION, dB	6.00	User Provided Reference Value
22 Prec AT GROUND, dBW	-187.21	(17)-(18)-(19)-(20)-(21)
23 GROUND G/T, dB/K	40.30	CLASS Database
24 TDRS Dwnlnk C/N0 (Thermal), dB-Hz	81.69	(22)+(23)-K
25 IM/XPOL DEGRADATION, dB	3.57	CLASS Analysis
26 TDRS Downlink C/N0 (TOTAL), dB-Hz	78.12	(24)-(25)
27 BANDWIDTH, dB-Hz	68.54	CLASS Database
28 TDRS Downlink C/N (TOTAL), dB	9.59	(26)-(27)

GROUND TERMINAL		
29 C/N AT GROUND, dB	-44.64	(16) || (28)
30 BANDWIDTH, dB-Hz	68.54	CLASS Database
31 MA NET COMBINER GAIN, dB	14.27	CLASS Database, inc. beamf. loss
32 C/N0 AT GROUND, dB-Hz	38.17	(29)+(30)+(31)

	I-Ch	Q-Ch	
33 CHANNEL POWER SPLIT, dB	-3.01	-3.01	User Provided Data
34 CHANNEL C/N0 AT GROUND, dB-Hz	35.16	35.16	(32)+(33)
35 BIT RATE, dB-BPS	30.00	30.00	User Provided Data
36 EB/N0 INTO DEMODULATOR, dB	5.16	5.16	(34)-(35)
37 DYNAMICS LOSS, dB	0.00	0.00	Not Considered
38 USER CONSTRAINT LOSS, dB	0.00	0.00	User Provided Data
39 RFI LOSS, dB	0.50	0.50	CLASS Analysis
40 IMPLEMENTATION LOSS, dB	3.10	3.10	CLASS Database
41 NET EB/N0, dB	1.56	1.56	(36)-(37)-(38)-(39)-(40)
42 THEORETICAL REQ EB/N0, dB	4.20	4.20	BER=1E-5
43 MARGIN, dB	-2.64	-2.64	(41)-(42)
44 COMBINED MARGIN, dB	0.36		CLASS Analysis

RETURN LINK COMPATIBILITY CHECK:

!!! The link is FULLY COMPATIBLE !!!

Link 4. GLAST SSA Return Link with 1 kbps Data Rate

```
          *** RETURN LINK CALCULATION -- NETWORK SYSTEMS ENGINEER ANALYSIS ***
  GSFC C.L.A.S.S. ANALYSIS #1       DATE & TIME: 03/10/04  11:10:50 PERFORMED BY: NANCY HUYNH
    USERID: GLAST                LINKID: SSA RTN              RELAY SYS.: TDRS-East TO STGT

        TYPE OF TRACKING:  PROGRAM TRACK                     FIELD OF VIEW:  PEFOV

SERVICE:  FREQUENCY:  DATA GROUP/MODE:  POLAR:  RANGE CASE:    ALTITUDE:    ELEVATION:    RANGE:
  SSA     2287.5 MHz   DG-1 MODE-2A      LCP     MAXIMUM      565.0 Km      1.5 Deg    44244.2 Km
----------------------------------------------------------------------------------------------------
                  I CHANNEL                                         Q CHANNEL

               DATA RATE =      1.000 KBPS               DATA RATE =      1.000 KBPS
               MOD 2 ADDED TO PN                         MOD 2 ADDED TO PN
               SYMBL FMT = NRZ-M                         SYMBL FMT = NRZ-M
               RATE 1/2 CODED                            RATE 1/2 CODED

               COMBINED                                  COMBINED
----------------------------------------------------------------------------------------------------
   SPACE-SPACE LINK                                                    NOTES
------------------------------------------------------               --------------------------------
 1 USER TRANSMIT POWER, dBW                           7.56             User Provided Data
 2 PASSIVE LOSS, dB                                   3.72             User Provided Data
 3 USER ANTENNA GAIN, dBi                            -1.70             User Provided Data
 4 POINTING LOSS, dB                                  0.00             User Provided Data
 5 USER EIRP, dBW                                     2.14             (1)-(2)+(3)-(4)
 6 SPACE LOSS, dB                                   192.55             CLASS Analysis
 7 ATMOSPHERIC LOSS, dB                               0.00             Not Considered
 8 MULTIPATH LOSS, dB                                 0.00             Not Considered
 9 POLARIZATION LOSS, dB                              0.67             User Provided Data
10 SSL RAIN ATTENUATION, dB                           0.00             User Provided Data
11 Prec AT INPUT TO TDRS, dBW                      -191.08             (5)-(6)-(7)-(8)-(9)-(10)
12 TDRS G/T, dB/K                                    10.49             CLASS Analysis
13 C/N0 AT TDRS, dB-Hz                               48.02             (11)+(12)-K
14 BANDWIDTH, dB-Hz                                  71.94             CLASS Database
15 C/N AT TDRS, dB                                  -23.92             (13)-(14)
------------------------------------------------------               --------------------------------
    SPACE-GROUND LINK
------------------------------------------------------               --------------------------------
16 TDRS EIRP, dBW                                    39.90             CLASS Database
17 PATH LOSS, dB                                    207.32             CLASS Analysis
18 ATMOSPHERIC LOSS, dB                               0.19             CLASS Analysis
19 POLARIZATION LOSS, dB                              0.03             CLASS Database
20 RAIN ATTENUATION, dB                               6.00             User Provided Reference Value
21 Prec AT GROUND, dBW                             -173.64             (16)-(17)-(18)-(19)-(20)
22 GROUND G/T, dB/K                                  40.30             CLASS Database
23 TDRS Dwnlnk C/N0 (Thermal), dB-Hz                 95.26             (21)+(22)-K
24 IM DEGRADATION, dB                                 1.19             CLASS Analysis
25 TDRS Downlink C/N0 (TOTAL), dB-Hz                 94.07             (23)-(24)
26 BANDWIDTH, dB-Hz                                  71.94             CLASS Database
27 TDRS Downlink C/N (TOTAL), dB                     22.13             (25)-(26)
------------------------------------------------------               --------------------------------
    GROUND TERMINAL
------------------------------------------------------               --------------------------------
28 C/N AT GROUND, dB                                -23.95             (15) || (27)
29 BANDWIDTH, dB-Hz                                  71.94             CLASS Database
30 C/N0 AT GROUND, dB-Hz                             47.99             (28)+(29)

                                                   I-Ch      Q-Ch
                                                   ----      ----
31 CHANNEL POWER SPLIT, dB                          -3.01     -3.01    User Provided Data
32 CHANNEL C/N0 AT GROUND, dB-Hz                    44.98     44.98    (30)+(31)
33 BIT RATE, dB-BPS                                 30.00     30.00    User Provided Data
34 EB/N0 INTO DEMODULATOR, dB                       14.98     14.98    (32)-(33)
35 DYNAMICS LOSS, dB                                 0.00      0.00    Not Considered
36 USER CONSTRAINT LOSS, dB                          0.00      0.00    User Provided Data
37 RFI LOSS, dB                                      0.70      0.70    CLASS Analysis
38 IMPLEMENTATION LOSS, dB                           3.10      3.10    CLASS Database
39 NET EB/N0, dB                                    11.18     11.18    (34)-(35)-(36)-(37)-(38)
40 THEORETICAL REQ EB/N0, dB                         4.20      4.20    BER=1E-5
41 MARGIN, dB                                        6.98      6.98    (39)-(40)
42 COMBINED MARGIN, dB                               9.98              CLASS Analysis

 ----------------------------------------------------------------------------------------------------
 RETURN LINK COMPATIBILITY CHECK:

   ....The link is FULLY COMPATIBLE....

 ----------------------------------------------------------------------------------------------------
```

Link 5. GLAST SSA Return Link with 2 kbps Data Rate

```
*** RETURN LINK CALCULATION -- NETWORK SYSTEMS ENGINEER ANALYSIS ***
GSFC C.L.A.S.S. ANALYSIS #1      DATE & TIME: 03/10/04  11:10:50 PERFORMED BY: NANCY HUYNH
USERID: GLAST                 LINKID: SSA RTN            RELAY SYS.: TDRS-East TO STGT

TYPE OF TRACKING:  PROGRAM TRACK                         FIELD OF VIEW:  PEFOV

SERVICE:  FREQUENCY:  DATA GROUP/MODE:  POLAR:  RANGE CASE:    ALTITUDE:    ELEVATION:    RANGE:
  SSA     2287.5 MHz   DG-1 MODE-2A      LCP      MAXIMUM      565.0 Km      1.5 Deg     44244.2 Km
```

I CHANNEL	Q CHANNEL
DATA RATE = 2.000 KBPS	DATA RATE = 2.000 KBPS
MOD 2 ADDED TO PN	MOD 2 ADDED TO PN
SYMBL FMT = NRZ-M	SYMBL FMT = NRZ-M
RATE 1/2 CODED	RATE 1/2 CODED
COMBINED	COMBINED

SPACE-SPACE LINK		NOTES
1 USER TRANSMIT POWER, dBW	7.56	User Provided Data
2 PASSIVE LOSS, dB	3.72	User Provided Data
3 USER ANTENNA GAIN, dBi	-1.70	User Provided Data
4 POINTING LOSS, dB	0.00	User Provided Data
5 USER EIRP, dBW	2.14	(1)-(2)+(3)-(4)
6 SPACE LOSS, dB	192.55	CLASS Analysis
7 ATMOSPHERIC LOSS, dB	0.00	Not Considered
8 MULTIPATH LOSS, dB	0.00	Not Considered
9 POLARIZATION LOSS, dB	0.67	User Provided Data
10 SSL RAIN ATTENUATION, dB	0.00	User Provided Data
11 Prec AT INPUT TO TDRS, dBW	-191.08	(5)-(6)-(7)-(8)-(9)-(10)
12 TDRS G/T, dB/K	10.49	CLASS Analysis
13 C/N0 AT TDRS, dB-Hz	48.02	(11)+(12)-K
14 BANDWIDTH, dB-Hz	71.94	CLASS Database
15 C/N AT TDRS, dB	-23.92	(13)-(14)

SPACE-GROUND LINK		
16 TDRS EIRP, dBW	39.90	CLASS Database
17 PATH LOSS, dB	207.32	CLASS Analysis
18 ATMOSPHERIC LOSS, dB	0.19	CLASS Analysis
19 POLARIZATION LOSS, dB	0.03	CLASS Database
20 RAIN ATTENUATION, dB	6.00	User Provided Reference Value
21 Prec AT GROUND, dBW	-173.64	(16)-(17)-(18)-(19)-(20)
22 GROUND G/T, dB/K	40.30	CLASS Database
23 TDRS Dwnlnk C/N0 (Thermal), dB-Hz	95.26	(21)+(22)-K
24 IM DEGRADATION, dB	1.19	CLASS Analysis
25 TDRS Downlink C/N0 (TOTAL), dB-Hz	94.07	(23)-(24)
26 BANDWIDTH, dB-Hz	71.94	CLASS Database
27 TDRS Downlink C/N (TOTAL), dB	22.13	(25)-(26)

GROUND TERMINAL	I-Ch	Q-Ch	
28 C/N AT GROUND, dB	-23.95		(15) || (27)
29 BANDWIDTH, dB-Hz	71.94		CLASS Database
30 C/N0 AT GROUND, dB-Hz	47.99		(28)+(29)
31 CHANNEL POWER SPLIT, dB	-3.01	-3.01	User Provided Data
32 CHANNEL C/N0 AT GROUND, dB-Hz	44.98	44.98	(30)+(31)
33 BIT RATE, dB-BPS	33.01	33.01	User Provided Data
34 EB/N0 INTO DEMODULATOR, dB	11.97	11.97	(32)-(33)
35 DYNAMICS LOSS, dB	0.00	0.00	Not Considered
36 USER CONSTRAINT LOSS, dB	0.00	0.00	User Provided Data
37 RFI LOSS, dB	0.70	0.70	CLASS Analysis
38 IMPLEMENTATION LOSS, dB	3.10	3.10	CLASS Database
39 NET EB/N0, dB	8.17	8.17	(34)-(35)-(36)-(37)-(38)
40 THEORETICAL REQ EB/N0, dB	4.20	4.20	BER=1E-5
41 MARGIN, dB	3.97	3.97	(39)-(40)
42 COMBINED MARGIN, dB	6.97		CLASS Analysis

RETURN LINK COMPATIBILITY CHECK:

....The link is FULLY COMPATIBLE....

Link 6. GLAST SSA Return Link with 4 kbps Data Rate

```
*** RETURN LINK CALCULATION -- NETWORK SYSTEMS ENGINEER ANALYSIS ***
GSFC C.L.A.S.S. ANALYSIS #1      DATE & TIME: 03/10/04  11:10:50 PERFORMED BY: NANCY HUYNH
USERID: GLAST                LINKID: SSA RTN              RELAY SYS.: TDRS-East TO STGT

TYPE OF TRACKING:  PROGRAM TRACK                      FIELD OF VIEW:  PEFOV

SERVICE:  FREQUENCY:  DATA GROUP/MODE:  POLAR:  RANGE CASE:    ALTITUDE:    ELEVATION:    RANGE:
  SSA     2287.5 MHz   DG-1 MODE-2A      LCP      MAXIMUM      565.0 Km      1.5 Deg     44244.2 Km
----------------------------------------------------------------------------------------------------
                   I CHANNEL                                         Q CHANNEL

               DATA RATE =      4.000 KBPS                 DATA RATE =      4.000 KBPS
               MOD 2 ADDED TO PN                           MOD 2 ADDED TO PN
               SYMBL FMT = NRZ-M                           SYMBL FMT = NRZ-M
               RATE 1/2 CODED                              RATE 1/2 CODED

               COMBINED                                    COMBINED
----------------------------------------------------------------------------------------------------
```

SPACE-SPACE LINK			NOTES
1 USER TRANSMIT POWER, dBW	7.56		User Provided Data
2 PASSIVE LOSS, dB	3.72		User Provided Data
3 USER ANTENNA GAIN, dBi	-1.70		User Provided Data
4 POINTING LOSS, dB	0.00		User Provided Data
5 USER EIRP, dBW	2.14		(1)-(2)+(3)-(4)
6 SPACE LOSS, dB	192.55		CLASS Analysis
7 ATMOSPHERIC LOSS, dB	0.00		Not Considered
8 MULTIPATH LOSS, dB	0.00		Not Considered
9 POLARIZATION LOSS, dB	0.67		User Provided Data
10 SSL RAIN ATTENUATION, dB	0.00		User Provided Data
11 Prec AT INPUT TO TDRS, dBW	-191.08		(5)-(6)-(7)-(8)-(9)-(10)
12 TDRS G/T, dB/K	10.49		CLASS Analysis
13 C/N0 AT TDRS, dB-Hz	48.02		(11)+(12)-K
14 BANDWIDTH, dB-Hz	71.94		CLASS Database
15 C/N AT TDRS, dB	-23.92		(13)-(14)
SPACE-GROUND LINK			
16 TDRS EIRP, dBW	39.90		CLASS Database
17 PATH LOSS, dB	207.32		CLASS Analysis
18 ATMOSPHERIC LOSS, dB	0.19		CLASS Analysis
19 POLARIZATION LOSS, dB	0.03		CLASS Database
20 RAIN ATTENUATION, dB	6.00		User Provided Reference Value
21 Prec AT GROUND, dBW	-173.64		(16)-(17)-(18)-(19)-(20)
22 GROUND G/T, dB/K	40.30		CLASS Database
23 TDRS Dwnlnk C/N0 (Thermal), dB-Hz	95.26		(21)+(22)-K
24 IM DEGRADATION, dB	1.19		CLASS Analysis
25 TDRS Downlink C/N0 (TOTAL), dB-Hz	94.07		(23)-(24)
26 BANDWIDTH, dB-Hz	71.94		CLASS Database
27 TDRS Downlink C/N (TOTAL), dB	22.13		(25)-(26)
GROUND TERMINAL			
28 C/N AT GROUND, dB	-23.95		(15) || (27)
29 BANDWIDTH, dB-Hz	71.94		CLASS Database
30 C/N0 AT GROUND, dB-Hz	47.99		(28)+(29)
	I-Ch	Q-Ch	
31 CHANNEL POWER SPLIT, dB	-3.01	-3.01	User Provided Data
32 CHANNEL C/N0 AT GROUND, dB-Hz	44.98	44.98	(30)+(31)
33 BIT RATE, dB-BPS	36.02	36.02	User Provided Data
34 EB/N0 INTO DEMODULATOR, dB	8.96	8.96	(32)-(33)
35 DYNAMICS LOSS, dB	0.00	0.00	Not Considered
36 USER CONSTRAINT LOSS, dB	0.00	0.00	User Provided Data
37 RFI LOSS, dB	0.70	0.70	CLASS Analysis
38 IMPLEMENTATION LOSS, dB	3.10	3.10	CLASS Database
39 NET EB/N0, dB	5.16	5.16	(34)-(35)-(36)-(37)-(38)
40 THEORETICAL REQ EB/N0, dB	4.20	4.20	BER=1E-5
41 MARGIN, dB	0.96	0.96	(39)-(40)
42 COMBINED MARGIN, dB	3.96		CLASS Analysis

RETURN LINK COMPATIBILITY CHECK:

....The link is FULLY COMPATIBLE....

Link 7. GLAST SSA Return Link with 8 kbps Data Rate

*** RETURN LINK CALCULATION -- NETWORK SYSTEMS ENGINEER ANALYSIS ***
GSFC C.L.A.S.S. ANALYSIS #1 DATE & TIME: 03/10/04 11:10:50 PERFORMED BY: NANCY HUYNH
USERID: GLAST LINKID: SSA RTN RELAY SYS.: TDRS-East TO STGT

TYPE OF TRACKING: PROGRAM TRACK FIELD OF VIEW: PEFOV

SERVICE:	FREQUENCY:	DATA GROUP/MODE:	POLAR:	RANGE CASE:	ALTITUDE:	ELEVATION:	RANGE:
SSA	2287.5 MHz	DG-1 MODE-2A	LCP	MAXIMUM	565.0 Km	1.5 Deg	44244.2 Km

I CHANNEL	Q CHANNEL
DATA RATE = 8.000 KBPS	DATA RATE = 8.000 KBPS
MOD 2 ADDED TO PN	MOD 2 ADDED TO PN
SYMBL FMT = NRZ-M	SYMBL FMT = NRZ-M
RATE 1/2 CODED	RATE 1/2 CODED
COMBINED	COMBINED

SPACE-SPACE LINK		NOTES
1 USER TRANSMIT POWER, dBW	7.56	User Provided Data
2 PASSIVE LOSS, dB	3.72	User Provided Data
3 USER ANTENNA GAIN, dBi	-1.70	User Provided Data
4 POINTING LOSS, dB	0.00	User Provided Data
5 USER EIRP, dBW	2.14	(1)-(2)+(3)-(4)
6 SPACE LOSS, dB	192.55	CLASS Analysis
7 ATMOSPHERIC LOSS, dB	0.00	Not Considered
8 MULTIPATH LOSS, dB	0.00	Not Considered
9 POLARIZATION LOSS, dB	0.67	User Provided Data
10 SSL RAIN ATTENUATION, dB	0.00	User Provided Data
11 Prec AT INPUT TO TDRS, dBW	-191.08	(5)-(6)-(7)-(8)-(9)-(10)
12 TDRS G/T, dB/K	10.49	CLASS Analysis
13 C/N0 AT TDRS, dB-Hz	48.02	(11)+(12)-K
14 BANDWIDTH, dB-Hz	71.94	CLASS Database
15 C/N AT TDRS, dB	-23.92	(13)-(14)

SPACE-GROUND LINK		
16 TDRS EIRP, dBW	39.90	CLASS Database
17 PATH LOSS, dB	207.32	CLASS Analysis
18 ATMOSPHERIC LOSS, dB	0.19	CLASS Analysis
19 POLARIZATION LOSS, dB	0.03	CLASS Database
20 RAIN ATTENUATION, dB	6.00	User Provided Reference Value
21 Prec AT GROUND, dBW	-173.64	(16)-(17)-(18)-(19)-(20)
22 GROUND G/T, dB/K	40.30	CLASS Database
23 TDRS Dwnlnk C/N0 (Thermal), dB-Hz	95.26	(21)+(22)-K
24 IM DEGRADATION, dB	1.19	CLASS Analysis
25 TDRS Downlink C/N0 (TOTAL), dB-Hz	94.07	(23)-(24)
26 BANDWIDTH, dB-Hz	71.94	CLASS Database
27 TDRS Downlink C/N (TOTAL), dB	22.13	(25)-(26)

GROUND TERMINAL		
28 C/N AT GROUND, dB	-23.95	(15) || (27)
29 BANDWIDTH, dB-Hz	71.94	CLASS Database
30 C/N0 AT GROUND, dB-Hz	47.99	(28)+(29)

	I-Ch	Q-Ch	
31 CHANNEL POWER SPLIT, dB	-3.01	-3.01	User Provided Data
32 CHANNEL C/N0 AT GROUND, dB-Hz	44.98	44.98	(30)+(31)
33 BIT RATE, dB-BPS	39.03	39.03	User Provided Data
34 EB/N0 INTO DEMODULATOR, dB	5.95	5.95	(32)-(33)
35 DYNAMICS LOSS, dB	0.00	0.00	Not Considered
36 USER CONSTRAINT LOSS, dB	0.00	0.00	User Provided Data
37 RFI LOSS, dB	0.70	0.70	CLASS Analysis
38 IMPLEMENTATION LOSS, dB	3.10	3.10	CLASS Database
39 NET EB/N0, dB	2.15	2.15	(34)-(35)-(36)-(37)-(38)
40 THEORETICAL REQ EB/N0, dB	4.20	4.20	BER=1E-5
41 MARGIN, dB	-2.05	-2.05	(39)-(40)
42 COMBINED MARGIN, dB	0.95		CLASS Analysis

RETURN LINK COMPATIBILITY CHECK:

....The link is FULLY COMPATIBLE....

Link 8. GLAST TDRSS Autotrack KuSA Return Link with 40 Mbps Data Rate

```
                *** RETURN LINK CALCULATION -- NETWORK SYSTEMS ENGINEER ANALYSIS ***
       GSFC C.L.A.S.S. ANALYSIS #1       DATE & TIME: 03/10/04  12:38: 7 PERFORMED BY: NANCY HUYNH
         USERID: GLAST                LINKID: KUSAR              RELAY SYS.: TDRS-East TO STGT

                TYPE OF TRACKING:  AUTOTRACK         TYPE OF K-BAND SERVICE: COMPOSITE

SERVICE:  FREQUENCY:  DATA GROUP/MODE:  POLAR:  RANGE CASE:    ALTITUDE:    ELEVATION:     RANGE:
  KuSA   15003.4 MHz    DG-2 MODE-2A     RCP      MAXIMUM       565.0 Km      1.5 Deg    44244.2 Km
----------------------------------------------------------------------------------------------------
                  I CHANNEL                                         Q CHANNEL

               DATA RATE =   20000.00 KBPS                DATA RATE =   20000.00 KBPS
               MOD TYPE = QPSK                            MOD TYPE = QPSK
               SYMBL FMT = NRZ-M                          SYMBL FMT = NRZ-M
               RATE 1/2 CODED                             RATE 1/2 CODED

----------------------------------------------------------------------------------------------------
   SPACE-SPACE LINK                                                     NOTES
------------------------------------------------------                  --------------------------------
 1 USER TRANSMIT POWER, dBW                              10.30          User Provided Data
 2 PASSIVE LOSS, dB                                       3.36          User Provided Data
 3 USER ANTENNA GAIN, dBi                                36.90          User Provided Data
 4 POINTING LOSS, dB                                      0.25          User Provided Data
 5 USER EIRP, dBW                                        43.59          (1)-(2)+(3)-(4)
 6 SPACE LOSS, dB                                       208.88          CLASS Analysis
 7 ATMOSPHERIC LOSS, dB                                   0.00          Not Considered
 8 MULTIPATH LOSS, dB                                     0.00          Not Considered
 9 POLARIZATION LOSS, dB                                  0.20          User Provided Data
10 SSL RAIN ATTENUATION, dB                               0.00          User Provided Data
11 Prec AT INPUT TO TDRS, dBW                          -165.49          (5)-(6)-(7)-(8)-(9)-(10)
12 TDRS G/T, dB/K                                        25.48          CLASS Analysis
13 C/N0 AT TDRS, dB-Hz                                   88.59          (11)+(12)-K
14 BANDWIDTH, dB-Hz                                      83.36          CLASS Database
15 C/N AT TDRS, dB                                        5.23          (13)-(14)
------------------------------------------------------                  --------------------------------
    SPACE-GROUND LINK
------------------------------------------------------                  --------------------------------
16 TDRS EIRP, dBW                                        47.40          CLASS Database
17 PATH LOSS, dB                                        207.32          CLASS Analysis
18 ATMOSPHERIC LOSS, dB                                   0.19          CLASS Analysis
19 POLARIZATION LOSS, dB                                  0.03          CLASS Database
20 RAIN ATTENUATION, dB                                   6.00          User Provided Reference Value
21 Prec AT GROUND, dBW                                 -166.14          (16)-(17)-(18)-(19)-(20)
22 GROUND G/T, dB/K                                      40.30          CLASS Database
23 TDRS Dwnlnk C/N0 (Thermal), dB-Hz                    102.76          (21)+(22)-K
24 IM DEGRADATION, dB                                     1.48          CLASS Analysis
25 TDRS Downlink C/N0 (TOTAL), dB-Hz                    101.28          (23)-(24)
26 BANDWIDTH, dB-Hz                                      83.36          CLASS Database
27 TDRS Downlink C/N (TOTAL), dB                         17.92          (25)-(26)
------------------------------------------------------                  --------------------------------
    GROUND TERMINAL
------------------------------------------------------                  --------------------------------
28 C/N AT GROUND, dB                                      4.93          (15) || (27)
29 BANDWIDTH, dB-Hz                                      83.36          CLASS Database
30 C/N0 AT GROUND, dB-Hz                                 88.29          (28)+(29)

                                                       I-Ch      Q-Ch
                                                       ----      ----
31 CHANNEL POWER SPLIT, dB                            -3.01     -3.01   User Provided Data
32 CHANNEL C/N0 AT GROUND, dB-Hz                      85.28     85.28   (30)+(31)
33 BIT RATE, dB-BPS                                   73.01     73.01   User Provided Data
34 EB/N0 INTO DEMODULATOR, dB                         12.27     12.27   (32)-(33)
35 DYNAMICS LOSS, dB                                   0.00      0.00   Not Considered
36 USER CONSTRAINT LOSS, dB                            0.00      0.00   User Provided Data
37 RFI LOSS, dB                                        0.00      0.00   CLASS Analysis
38 IMPLEMENTATION LOSS, dB                             2.78      2.78   CLASS Database
39 NET EB/N0, dB                                       9.49      9.49   (34)-(35)-(36)-(37)-(38)
40 THEORETICAL REQ EB/N0, dB                           4.20      4.20   BER=1E-5
41 MARGIN, dB                                          5.29      5.29   (39)-(40)

 ----------------------------------------------------------------------------------------------------
 RETURN LINK COMPATIBILITY CHECK:

   !!! The link is FULLY COMPATIBLE !!!

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```

Link 9. GLAST TDRSS LEO Track KuSA Return Link with 40 Mbps Data Rate

```
                *** RETURN LINK CALCULATION -- NETWORK SYSTEMS ENGINEER ANALYSIS ***
      GSFC C.L.A.S.S. ANALYSIS #1       DATE & TIME: 03/10/04  12:39:47 PERFORMED BY: NANCY HUYNH
        USERID: GLAST               LINKID: KUSAR               RELAY SYS.: TDRS-East TO STGT

               TYPE OF TRACKING:  LEO TRACK         TYPE OF K-BAND SERVICE: COMPOSITE

SERVICE:  FREQUENCY:  DATA GROUP/MODE:  POLAR:  RANGE CASE:    ALTITUDE:    ELEVATION:     RANGE:
  KuSA   15003.4 MHz    DG-2 MODE-2A     RCP      MAXIMUM       565.0 Km      1.5 Deg    44244.2 Km
----------------------------------------------------------------------------------------------------
                    I CHANNEL                                         Q CHANNEL

               DATA RATE =   20000.00 KBPS                  DATA RATE =   20000.00 KBPS
               MOD TYPE = QPSK                              MOD TYPE = QPSK
               SYMBL FMT = NRZ-M                            SYMBL FMT = NRZ-M
               RATE 1/2 CODED                               RATE 1/2 CODED
```

SPACE-SPACE LINK		NOTES
1 USER TRANSMIT POWER, dBW	10.30	User Provided Data
2 PASSIVE LOSS, dB	3.36	User Provided Data
3 USER ANTENNA GAIN, dBi	36.90	User Provided Data
4 POINTING LOSS, dB	0.25	User Provided Data
5 USER EIRP, dBW	43.59	(1)-(2)+(3)-(4)
6 SPACE LOSS, dB	208.88	CLASS Analysis
7 ATMOSPHERIC LOSS, dB	0.00	Not Considered
8 MULTIPATH LOSS, dB	0.00	Not Considered
9 POLARIZATION LOSS, dB	0.20	User Provided Data
10 SSL RAIN ATTENUATION, dB	0.00	User Provided Data
11 Prec AT INPUT TO TDRS, dBW	-165.49	(5)-(6)-(7)-(8)-(9)-(10)
12 TDRS G/T, dB/K	22.98	CLASS Analysis
13 C/N0 AT TDRS, dB-Hz	86.09	(11)+(12)-K
14 BANDWIDTH, dB-Hz	83.36	CLASS Database
15 C/N AT TDRS, dB	2.73	(13)-(14)

SPACE-GROUND LINK		
16 TDRS EIRP, dBW	47.40	CLASS Database
17 PATH LOSS, dB	207.32	CLASS Analysis
18 ATMOSPHERIC LOSS, dB	0.19	CLASS Analysis
19 POLARIZATION LOSS, dB	0.03	CLASS Database
20 RAIN ATTENUATION, dB	6.00	User Provided Reference Value
21 Prec AT GROUND, dBW	-166.14	(16)-(17)-(18)-(19)-(20)
22 GROUND G/T, dB/K	40.30	CLASS Database
23 TDRS Dwnlnk C/N0 (Thermal), dB-Hz	102.76	(21)+(22)-K
24 IM DEGRADATION, dB	1.48	CLASS Analysis
25 TDRS Downlink C/N0 (TOTAL), dB-Hz	101.28	(23)-(24)
26 BANDWIDTH, dB-Hz	83.36	CLASS Database
27 TDRS Downlink C/N (TOTAL), dB	17.92	(25)-(26)

GROUND TERMINAL		
28 C/N AT GROUND, dB	2.53	(15) || (27)
29 BANDWIDTH, dB-Hz	83.36	CLASS Database
30 C/N0 AT GROUND, dB-Hz	85.89	(28)+(29)

	I-Ch	Q-Ch	
31 CHANNEL POWER SPLIT, dB	-3.01	-3.01	User Provided Data
32 CHANNEL C/N0 AT GROUND, dB-Hz	82.88	82.88	(30)+(31)
33 BIT RATE, dB-BPS	73.01	73.01	User Provided Data
34 EB/N0 INTO DEMODULATOR, dB	9.87	9.87	(32)-(33)
35 DYNAMICS LOSS, dB	0.00	0.00	Not Considered
36 USER CONSTRAINT LOSS, dB	0.00	0.00	User Provided Data
37 RFI LOSS, dB	0.00	0.00	CLASS Analysis
38 IMPLEMENTATION LOSS, dB	2.78	2.78	CLASS Database
39 NET EB/N0, dB	7.09	7.09	(34)-(35)-(36)-(37)-(38)
40 THEORETICAL REQ EB/N0, dB	4.20	4.20	BER=1E-5
41 MARGIN, dB	2.89	2.89	(39)-(40)

RETURN LINK COMPATIBILITY CHECK:

!!! The link is FULLY COMPATIBLE !!!

Link 10. GLAST Uplink Link Through 11.3-m WGS with 2 kbps Data Rate

TABLE A-1 UPLINK DATE & TIME: 03/03/04 14:36:17
GLAST
FREQUENCY - 2106.400 MHZ
GROUND ANTENNA - WGS - 11.3-METER @ WALLOPS
POWER - 0.2000 K WATTS
PCM/PSK/PM – SUBCARRIER FREQ.= 16 KHZ – DATA FORMAT = NRZ-M
DATA RATE: 2.0 KBPS

PARAMETERS	UNITS	VALUES (MAX RNG: 2243.31 KM 5.0 EL)	VALUES (MIN RNG: 565.00 KM 90.0 EL)	ESTIMATED TOLERANCES DB FAV	ESTIMATED TOLERANCES DB ADV
EFFECTIVE RADIATED POWER	DBM	96.0	96.0	1.0	-1.0
FREE SPACE DISPERSION LOSS	DB	-165.9	-154.0	0.0	0.0
ATMOSPHERIC LOSS	DB	-0.4	0.0	0.0	0.0
POLARIZATION LOSS	DB	-0.7	-0.7	0.0	0.0
SPACECRAFT ANTENNA GAIN	DBI	-2.7	-2.7	0.0	0.0
SPACECRAFT PASSIVE LOSS	DB	-2.9	-2.9	0.3	-0.3
MAXIMUM TOTAL RECEIVED POWER	DBM	-76.6	-64.3	1.0	-1.0
SPACECRAFT ANTENNA NULL DEPTH	DB	0.0	0.0	0.0	0.0
MINIMUM TOTAL RECEIVED POWER	DBM	-76.6	-64.3	1.0	-1.0
SYSTEM NOISE DENSITY	DBM/HZ	-171.4	-171.4	0.0	0.0
IF NOISE BANDWIDTH(3000.000 KHZ)	DB-HZ	64.8	64.8	0.0	0.0
IF NOISE POWER	DBM	-106.6	-106.6	0.0	0.0
IF SNR (MIN)	DB	30.0	42.3	1.0	-1.0

CARRIER CHANNEL

CARRIER/TOTAL POWER	DB	-2.3	-2.3	0.2	-0.2
RECEIVED CARRIER POWER	DBM	-78.9	-66.6	1.1	-1.1
CARRIER LOOP NOISE BW(800. HZ)	DB-HZ	29.0	29.0	0.0	0.0
NOISE POWER	DBM	-142.4	-142.4	0.0	0.0
CARRIER/NOISE	DB	63.5	75.8	1.1	-1.1
REQUIRED CARRIER/NOISE	DB	20.0	20.0	0.0	0.0
AVAILABLE CARRIER MARGIN	DB	43.5	55.8	1.1	-1.1
REQUIRED PERFORMANCE MARGIN	DB	0.0	0.0	0.0	0.0
NET MARGIN	DB	43.5	55.8	1.1	-1.1

COMMAND CHANNEL (PCM/PSK/PM)

COMMAND/TOTAL POWER(MI=1.00 RAD)	DB	-4.1	-4.1	0.4	-0.4
RECEIVED COMMAND POWER	DBM	-80.7	-68.4	1.1	-1.1
PREDETECTION (PSK) NOISE BW(32.000 KHZ)	DB-HZ	45.1	45.1	0.0	0.0
PREDETECTION (PSK) NOISE POWER	DB	-126.3	-126.3	0.0	0.0
PREDETECTION (PSK) SNR	DB	45.6	57.9	1.1	-1.1
COMMAND DATA RATE (2.000KBPS)	DB-BPS	33.0	33.0	0.0	0.0
AVAILABLE ENERGY PER BIT/NOISE DENSITY	DB	57.7	70.0	1.1	-1.1
DECODER DEGRADATION	DB	-2.4	-2.4	0.0	0.0
REQUIRED ENERGY PER BIT/NOISE DENSITY (BER=E-5)	DB	9.6	9.6	0.0	0.0
AVAILABLE COMMAND MARGIN	DB	45.7	58.0	1.1	-1.1
REQUIRED PERFORMANCE MARGIN	DB	0.0	0.0	0.0	0.0
NET MARGIN	DB	45.7	58.0	1.1	-1.1

Link 11. GLAST Uplink Link Through 9-m MILA with 2 kbps Data Rate

TABLE A-1 UPLINK DATE & TIME: 03/03/04 14:40: 4
GLAST
FREQUENCY - 2106.400 MHZ
GROUND ANTENNA - MILA - 9-M @ FLORIDA
POWER - 0.2000 K WATTS
PCM/PSK/PM – SUBCARRIER FREQ.= 16 KHZ – DATA FORMAT = NRZ-M
DATA RATE: 2.0 KBPS

PARAMETERS	UNITS	VALUES (MAX RNG: 2243.31 KM 5.0 EL)	VALUES (MIN RNG: 565.00 KM 90.0 EL)	ESTIMATED TOLERANCES DB FAV	ESTIMATED TOLERANCES DB ADV
EFFECTIVE RADIATED POWER	DBM	93.0	93.0	1.0	-1.0
FREE SPACE DISPERSION LOSS	DB	-165.9	-154.0	0.0	0.0
ATMOSPHERIC LOSS	DB	-0.4	0.0	0.0	0.0
POLARIZATION LOSS	DB	-0.7	-0.7	0.0	0.0
SPACECRAFT ANTENNA GAIN	DBI	-2.7	-2.7	0.0	0.0
SPACECRAFT PASSIVE LOSS	DB	-2.9	-2.9	0.3	-0.3
MAXIMUM TOTAL RECEIVED POWER	DBM	-79.6	-67.3	1.0	-1.0
SPACECRAFT ANTENNA NULL DEPTH	DB	0.0	0.0	0.0	0.0
MINIMUM TOTAL RECEIVED POWER	DBM	-79.6	-67.3	1.0	-1.0
SYSTEM NOISE DENSITY	DBM/HZ	-171.4	-171.4	0.0	0.0
IF NOISE BANDWIDTH(3000.000 KHZ)	DB-HZ	64.8	64.8	0.0	0.0
IF NOISE POWER	DBM	-106.6	-106.6	0.0	0.0
IF SNR (MIN)	DB	27.0	39.3	1.0	-1.0
CARRIER CHANNEL					
CARRIER/TOTAL POWER	DB	-2.3	-2.3	0.2	-0.2
RECEIVED CARRIER POWER	DBM	-81.9	-69.6	1.1	-1.1
CARRIER LOOP NOISE BW(800. HZ)	DB-HZ	29.0	29.0	0.0	0.0
NOISE POWER	DBM	-142.4	-142.4	0.0	0.0
CARRIER/NOISE	DB	60.5	72.8	1.1	-1.1
REQUIRED CARRIER/NOISE	DB	20.0	20.0	0.0	0.0
AVAILABLE CARRIER MARGIN	DB	40.5	52.8	1.1	-1.1
REQUIRED PERFORMANCE MARGIN	DB	0.0	0.0	0.0	0.0
NET MARGIN	DB	40.5	52.8	1.1	-1.1
COMMAND CHANNEL (PCM/PSK/PM)					
COMMAND/TOTAL POWER(MI=1.00 RAD)	DB	-4.1	-4.1	0.4	-0.4
RECEIVED COMMAND POWER	DBM	-83.7	-71.4	1.1	-1.1
PREDETECTION (PSK) NOISE BW(32.000 KHZ)	DB-HZ	45.1	45.1	0.0	0.0
PREDETECTION (PSK) NOISE POWER	DB	-126.3	-126.3	0.0	0.0
PREDETECTION (PSK) SNR	DB	42.6	54.9	1.1	-1.1
COMMAND DATA RATE (2.000KBPS)	DB-BPS	33.0	33.0	0.0	0.0
AVAILABLE ENERGY PER BIT/NOISE DENSITY	DB	54.7	67.0	1.1	-1.1
DECODER DEGRADATION	DB	-2.4	-2.4	0.0	0.0
REQUIRED ENERGY PER BIT/NOISE DENSITY (BER=E-5)	DB	9.6	9.6	0.0	0.0
AVAILABLE COMMAND MARGIN	DB	42.7	55.0	1.1	-1.1
REQUIRED PERFORMANCE MARGIN	DB	0.0	0.0	0.0	0.0
NET MARGIN	DB	42.7	55.0	1.1	-1.1

Link 12. GLAST Uplink Link Through 13-m USN with 2 kbps Data Rate

TABLE A-1 UPLINK DATE & TIME: 03/03/04 14:33:48
GLAST
FREQUENCY - 2106.400 MHZ
GROUND ANTENNA - USN - 13-METER AT HAWAII
POWER - 0.2000 K WATTS
PCM/PSK/PM – SUBCARRIER FREQ.= 16 KHZ – DATA FORMAT = NRZ-M
DATA RATE: 2.0 KBPS

PARAMETERS	UNITS	VALUES (MAX RNG: 2243.31 KM 5.0 EL)	VALUES (MIN RNG: 565.00 KM 90.0 EL)	ESTIMATED TOLERANCES DB FAV	ESTIMATED TOLERANCES DB ADV
EFFECTIVE RADIATED POWER	DBM	98.0	98.0	1.0	-1.0
FREE SPACE DISPERSION LOSS	DB	-165.9	-154.0	0.0	0.0
ATMOSPHERIC LOSS	DB	-0.4	0.0	0.0	0.0
POLARIZATION LOSS	DB	-0.7	-0.7	0.0	0.0
SPACECRAFT ANTENNA GAIN	DBI	-2.7	-2.7	0.0	0.0
SPACECRAFT PASSIVE LOSS	DB	-2.9	-2.9	0.3	-0.3
MAXIMUM TOTAL RECEIVED POWER	DBM	-74.6	-62.3	1.0	-1.0
SPACECRAFT ANTENNA NULL DEPTH	DB	0.0	0.0	0.0	0.0
MINIMUM TOTAL RECEIVED POWER	DBM	-74.6	-62.3	1.0	-1.0
SYSTEM NOISE DENSITY	DBM/HZ	-171.4	-171.4	0.0	0.0
IF NOISE BANDWIDTH(3000.000 KHZ)	DB-HZ	64.8	64.8	0.0	0.0
IF NOISE POWER	DBM	-106.6	-106.6	0.0	0.0
IF SNR (MIN)	DB	32.0	44.3	1.0	-1.0
CARRIER CHANNEL					
CARRIER/TOTAL POWER	DB	-2.3	-2.3	0.2	-0.2
RECEIVED CARRIER POWER	DBM	-76.9	-64.6	1.1	-1.1
CARRIER LOOP NOISE BW(800. HZ)	DB-HZ	29.0	29.0	0.0	0.0
NOISE POWER	DBM	-142.4	-142.4	0.0	0.0
CARRIER/NOISE	DB	65.5	77.8	1.1	-1.1
REQUIRED CARRIER/NOISE	DB	20.0	20.0	0.0	0.0
AVAILABLE CARRIER MARGIN	DB	45.5	57.8	1.1	-1.1
REQUIRED PERFORMANCE MARGIN	DB	0.0	0.0	0.0	0.0
NET MARGIN	DB	42.5	54.8	1.1	-1.1
COMMAND CHANNEL (PCM/PSK/PM)					
COMMAND/TOTAL POWER(MI=1.00 RAD)	DB	-4.1	-4.1	0.4	-0.4
RECEIVED COMMAND POWER	DBM	-78.7	-66.4	1.1	-1.1
PREDETECTION (PSK) NOISE BW(32.000 KHZ)	DB-HZ	45.1	45.1	0.0	0.0
PREDETECTION (PSK) NOISE POWER	DB	-126.3	-126.3	0.0	0.0
PREDETECTION (PSK) SNR	DB	47.6	59.9	1.1	-1.1
COMMAND DATA RATE (2.000KBPS)	DB-BPS	33.0	33.0	0.0	0.0
AVAILABLE ENERGY PER BIT/NOISE DENSITY	DB	59.7	72.0	1.1	-1.1
DECODER DEGRADATION	DB	-2.4	-2.4	0.0	0.0
REQUIRED ENERGY PER BIT/NOISE DENSITY (BER=E-5)	DB	9.6	9.6	0.0	0.0
AVAILABLE COMMAND MARGIN	DB	47.7	60.0	1.1	-1.1
REQUIRED PERFORMANCE MARGIN	DB	0.0	0.0	0.0	0.0
NET MARGIN	DB	47.7	60.0	1.1	-1.1

Link 13. GLAST Downlink Link Through 11.3-m WGS with 2.5 Mbps Data Rate

*** DOWNLINK MARGIN CALCULATION***
GSFC C.L.A.S.S. ANALYSIS ##1 DATE & TIME: 3/ 3/ 4 13:53:52 PERFORMED BY: NANCY HUYNH
LINKID: GLAST THROUGH 11.3-M WGS

FREQUENCY: 2287.5 MHz RANGE: 2243.3 km POLARIZATION: LHCP

MODULATION: QPSK

I CHANNEL	Q CHANNEL
DATA RATE: 1250.000 kbps	DATA RATE: 1250.000 kbps
CODING: RATE 1/2 CODED	CODING: RATE 1/2 CODED
BER: 1.00E-05	BER: 1.00E-05

GLAST DOWNLINK TO WALLOPS 11M

PARAMETER	VALUE		REMARKS
01. USER SPACECRAFT TRANSMITTER POWER - dBW	7.56		NOTE A; 5.7 WATTS
02. USER SPACECRAFT PASSIVE LOSS - dB	3.72		NOTE A
03. USER SPACECRAFT ANTENNA GAIN - dBi	-1.70		NOTE A
04. USER SPACECRAFT POINTING LOSS - dB	0.00		NOTE A
05. USER SPACECRAFT EIRP - dBWi	2.14		1-2+3-4
06. COMBINER LOSS - dB	0.50		NOTE A
07. FREE SPACE LOSS - dB	166.65		NOTE B; ALT:565.0 KM EL: 5.0 DEG
08. ATMOSPHERIC LOSS - dB	0.40		NOTE B
09. RAIN ATTENUATION - dB	0.18		NOTE B; ITU MODEL; EXC: 0.01% RRATE.01%:45.79 mm/hr RHGT: 3.8 km
10. MULTIPATH LOSS - dB	0.00		NOTE A
11. GROUND STATION G/T - dB/DEGREES-K	21.00		NOTE A
12. BOLTZMANN'S CONSTANT - dBW/(Hz*K)	-228.60		CONSTANT
13. RECEIVED CARRIER TO NOISE DENSITY - dB/Hz	84.01		5-6-7-8-9-10+11-12
	I CHANNEL	Q CHANNEL	
14. I-Q CHANNEL POWER SPLIT LOSS - dB	3.01	3.01	NOTE B; 1.00 TO 1.00
15. MODULATION LOSS - dB	0.00	0.00	NOTE A
16. DATA RATE - dB-bps	60.97	60.97	NOTE A
17. DIFFERENTIAL ENCODING/DECODING LOSS - dB	0.00	0.00	NOTE A
18. USER CONSTRAINT LOSS - dB	0.00	0.00	NOTE A
19. RECEIVED Eb/No - dB	20.03	20.03	13-14-15-16-17-18
20. IMPLEMENTATION LOSS - dB	2.00	2.00	NOTE A
21. REQUIRED Eb/No - dB	4.40	4.40	I: NOTE A; Q: NOTE A
22. REQUIRED PERFORMANCE MARGIN - dB	0.00	0.00	NOTE A
23. MARGIN - dB	13.63	13.63	19-20-21-22

NOTE A: PARAMETER VALUE FROM USER PROJECT - SUBJECT TO CHANGE
NOTE B: FROM CLASS ANALYSIS IF COMPUTED

Link 14. GLAST Downlink Link Through 9-M MILA with 2.5 Mbps Data Rate

```
                         *** DOWNLINK MARGIN CALCULATION***
  GSFC C.L.A.S.S. ANALYSIS ##1  DATE & TIME:  3/ 10/04 12: 0:23  PERFORMED BY: NANCY HUYNH
                          LINKID:  GLAST THROUGH MILA 9-M

     FREQUENCY:  2287.5 MHz          RANGE:  2243.3 km          POLARIZATION:  LHCP

                              MODULATION:  QPSK
              I CHANNEL                               Q CHANNEL
              ---------                               ---------
     DATA RATE:  1250.000 kbps               DATA RATE:  1250.000 kbps
        CODING:  RATE 1/2 CODED                 CODING:  RATE 1/2 CODED
           BER:  1.00E-05                          BER:  1.00E-05


     GLAST DOWNLINK TO WALLOPS 11M
```

PARAMETER	VALUE		REMARKS
01. USER SPACECRAFT TRANSMITTER POWER - dBW	7.56		NOTE A; 5.7 WATTS
02. USER SPACECRAFT PASSIVE LOSS - dB	3.72		NOTE A
03. USER SPACECRAFT ANTENNA GAIN - dBi	-1.70		NOTE A
04. USER SPACECRAFT POINTING LOSS - dB	0.00		NOTE A
05. USER SPACECRAFT EIRP - dBWi	2.14		1-2+3-4
06. COMBINER LOSS - dB	0.50		NOTE A
07. FREE SPACE LOSS - dB	166.65		NOTE B; ALT:565.0 KM EL: 5.0 DEG
08. ATMOSPHERIC LOSS - dB	0.40		NOTE B
09. RAIN ATTENUATION - dB	0.47		NOTE B; ITU MODEL; EXC: 0.01% RRATE.01%:92.65 mm/hr RHGT: 4.5 km
10. MULTIPATH LOSS - dB	0.00		NOTE A
11. GROUND STATION G/T - dB/DEGREES-K	22.00		NOTE A
12. BOLTZMANN'S CONSTANT - dBW/(Hz*K)	-228.60		CONSTANT
13. RECEIVED CARRIER TO NOISE DENSITY - dB/Hz	84.72		5-6-7-8-9-10+11-12
	I CHANNEL	Q CHANNEL	
14. I-Q CHANNEL POWER SPLIT LOSS - dB	3.01	3.01	NOTE B; 1.00 TO 1.00
15. MODULATION LOSS - dB	0.00	0.00	NOTE A
16. DATA RATE - dB-bps	60.97	60.97	NOTE A
17. DIFFERENTIAL ENCODING/DECODING LOSS - dB	0.00	0.00	NOTE A
18. USER CONSTRAINT LOSS - dB	0.00	0.00	NOTE A
19. RECEIVED Eb/No - dB	20.74	20.74	13-14-15-16-17-18
20. IMPLEMENTATION LOSS - dB	2.00	2.00	NOTE A
21. REQUIRED Eb/No - dB	4.40	4.40	I: NOTE A; Q: NOTE A
22. REQUIRED PERFORMANCE MARGIN - dB	0.00	0.00	NOTE A
23. MARGIN - dB	14.34	14.34	19-20-21-22

NOTE A: PARAMETER VALUE FROM USER PROJECT - SUBJECT TO CHANGE
NOTE B: FROM CLASS ANALYSIS IF COMPUTED

Link 15. GLAST Downlink Link Through 13-M USN with 2.5 Mbps Data Rate

```
                        *** DOWNLINK MARGIN CALCULATION***
   GSFC C.L.A.S.S. ANALYSIS ##1  DATE & TIME:  3/ 10/ 4 12: 3:45  PERFORMED BY: NANCY HUYNH
                       LINKID:  GLAST THROUGH USN HAWAII 13-M

   FREQUENCY:  2287.5 MHz          RANGE:  2243.3 km          POLARIZATION:  RHCP

                              MODULATION:  QPSK
               I CHANNEL                              Q CHANNEL
               ---------                              ---------
          DATA RATE:  1250.000 kbps              DATA RATE:  1250.000 kbps
             CODING:  RATE 1/2 CODED                CODING:  RATE 1/2 CODED
                BER:  1.00E-05                         BER:  1.00E-05


         GLAST DOWNLINK TO WALLOPS 11M
```

PARAMETER	VALUE		REMARKS
01. USER SPACECRAFT TRANSMITTER POWER - dBW	7.56		NOTE A; 5.7 WATTS
02. USER SPACECRAFT PASSIVE LOSS - dB	3.72		NOTE A
03. USER SPACECRAFT ANTENNA GAIN - dBi	-1.70		NOTE A
04. USER SPACECRAFT POINTING LOSS - dB	0.00		NOTE A
05. USER SPACECRAFT EIRP - dBWi	2.14		1 - 2 + 3 - 4
06. COMBINER LOSS - dB	0.50		NOTE A
07. FREE SPACE LOSS - dB	166.65		NOTE B; ALT: 565.0 KM EL: 5.0 DEG
08. ATMOSPHERIC LOSS - dB	0.40		NOTE B
09. RAIN ATTENUATION - dB	0.32		NOTE B; ITU MODEL; EXC: 0.01% RRATE.01%:38.01 mm/hr RHGT: 4.9 km
10. MULTIPATH LOSS - dB	0.00		NOTE A
11. GROUND STATION G/T - dB/DEGREES-K	23.00		NOTE A
12. BOLTZMANN'S CONSTANT - dBW/(Hz*K)	-228.60		CONSTANT
13. RECEIVED CARRIER TO NOISE DENSITY - dB/Hz	85.87		5-6-7-8-9-10+11-12
	I CHANNEL	Q CHANNEL	
14. I-Q CHANNEL POWER SPLIT LOSS - dB	3.01	3.01	NOTE B; 1.00 TO 1.00
15. MODULATION LOSS - dB	0.00	0.00	NOTE A
16. DATA RATE - dB-bps	60.97	60.97	NOTE A
17. DIFFERENTIAL ENCODING/DECODING LOSS - dB	0.00	0.00	NOTE A
18. USER CONSTRAINT LOSS - dB	0.00	0.00	NOTE A
19. RECEIVED Eb/No - dB	21.89	21.89	13-14-15-16-17-18
20. IMPLEMENTATION LOSS - dB	2.00	2.00	NOTE A
21. REQUIRED Eb/No - dB	4.40	4.40	I: NOTE A; Q: NOTE A
22. REQUIRED PERFORMANCE MARGIN - dB	0.00	0.00	NOTE A
23. MARGIN - dB	15.49	15.49	19-20-21-22

NOTE A: PARAMETER VALUE FROM USER PROJECT - SUBJECT TO CHANGE
NOTE B: FROM CLASS ANALYSIS IF COMPUTED

Appendix B. GLAST Antenna Patterns

TBD

Appendix C. Abbreviations and Acronyms

Acronym	Definition
AM/PM	Amplitude Modulation to Phase Modulation (Ratio)
AOS	Advanced Orbiting Systems
BAT	Burst Alert Telescope
BER	Bit Error Rate
BPSK	Biphase Shift Key
BRF	Band Reject Filter
CCIR	Consultative Committee International Radio
C&DH	Command and Data Handling
C&T	Communications and Tracking
C/T	Received power to noise spectral density ratio
CCSDS	Consultative Committee for Space Data Systems
CDRL	Contract Document Requirements List
CDU	Control and Data Unit
CLCW	Command Link Control Word
CLTU	Command Link Transmission Unit
CMD	Command
COP	Command Operation Procedure
COP-1	Command Operation Procedure, Version 1
C&T	Communications and Tracking
CTV	Compatibility Test Van
CVCDU	Coded Virtual Channel Data Unit
DAS	Demand Access System
dBc	Decibel Below Unmodulated Carrier
DG	Data Group
DMR	Detail Mission Requirements
EIRP	Effective Isotropic Radiated Power
EOR	Excusive OR Logic Operation
FARM	Frame Acceptance and Reporting Mechanism

Acronym	Definition
FDF	Flight Dynamics Facility
FEC	Forward Error Correction
FOP	Frame Operation Procedure
G/T	System Gain-to-Noise Temperature Ratio (Db/^{O} K)
GN	Ground Network
GRB	Gamma Ray Bursts
GSFC	Goddard Space Flight Center
GSTDN	Ground Spaceflight Tracking And Data Network
HLD	High Level Discrete
Hz	Hertz
ICD	Interface Control Document
ID	Identification
JPL	Jet Propulsion Laboratory
kbps	Kilo Bits Per Second
kHz	Kilo Hertz
LHC	Left-Hand Circular
LHCP	Left-Hand Circular Polarization
LMMS	Lockheed Martin Missiles and Space
MA	Multiple Access
MAF	Multiple Access Forward
MAR	Multiple Access Return
Mbps	Mega Bits Per Second
MHz	Mega Hertz
MSPO	Mission Services Program Office
NASA	National Aeronautic and Space Administration
NRZ-M	Non-Return-To-Zero Mark
POCC	Project Operations Control Center
PSK	Phase Shift Key
PSLA	Project Service Level Agreement
QPSK	Qudraphase
RF	Radio Frequency

Acronym	Definition
RFI	Radio Frequency Interference
SOH	State of Health
SQPN	Staggered Quadraphase Pseudorandom Noise
SSA	S-band Single Access
SSAF	S-band Single Access Forward
SSAR	S-band Single Access Return
SSR	Solid state recorder
STDN	Satellite Telemetry Data Network
TCXO	Temperature Compensated Crystal Oscillator
TDRS	Tracking and Data Relay Satellite
TDRSS	Tracking and Data Relay Satellite System
TGBF	Third Generation Beamformer
TLM	Telemetry
ToOs	Targets of Opportunities
UQPSK	Unbalanced Quadrature Phase Shift Key
VCDU	Virtual Channel Data Unit
WDISC	White Sands Complex Transmission Control Protocol/Internet Protocol Data Interface Service Capability
WSC	White Sands Complex

Radio Frequency Interface Control Document (RFICD) between the Gamma-ray Large Space Telescope (GLAST) Observatory and the Space Network (SN) and the Ground Network (GN)